2843

FILE COPY

Rice and Sturgeon Lakes Nutrient Budget Study

Rice Lake Macrophytes: Distribution, Composition, Biomass, Tissue Nutrient Content, and Ecological Significance.

R/S Technical Report No. 7, February 1994

Ontario
Ministry of Environment and Energy
Ministry of Natural Resources

Environment Canada Parks Service
Environnement Canada Service des parcs

Trent-Severn Waterway
Voie navigable Trent-Severn

ISBN 0-7778-1131-6

RICE LAKE MACROPHYTES: DISTRIBUTION, COMPOSITION, BIOMASS, TISSUE NUTRIENT CONTENT, AND ECOLOGICAL SIGNIFICANCE

FEBRUARY 1994

Cette publication technique
n'est disponible qu'en anglais.

Copyright: Queen's Printer for Ontario, 1994
This publication may be reproduced for non-commercial purposes
with appropriate attribution.

PIBS 2843

RICE LAKE MACROPHYTES: DISTRIBUTION, COMPOSITION, BIOMASS TISSUE NUTRIENT CONTENT AND ECOLOGICAL SIGNIFICANCE

Report prepared by:

Limnos Limited
591 Liverpool Road
Pickering, ON
L1W 1R1

PREFACE

The Kawartha lakes are a large and economically important system of eight large lakes which are located in central Ontario. Sturgeon Lake and Rice Lake are located near the upper and lower ends of the Kawartha Lakes system respectively and both support significant amounts of urban and recreational development. They were chosen for detailed study because of their importance within the system and because both have shown the symptoms associated with excessive nutrient input for several years.

The Rice and Sturgeon Lakes Nutrient Budget Study was initiated to investigate linkages between point and non-point sources of nutrients, water quality, and aquatic life within the lakes and to estimate the impacts of these processes on in-lake water quality.

The study was supervised by the Rice - Sturgeon Lakes Nutrient Budget Technical Committee which had representatives from the Limnology Section (Water Resources Branch) and Central Region of the Ontario Ministry of the Environment and Energy, the Trent Severn Waterway (Environment Canada) and the Kawartha Lakes Fisheries Assessment Unit of the Ontario Ministry of Natural Resources.

This is one of a series of technical reports. These and the summary report (R/S Tech. Rep. No. 13) will provide a technical basis for the management of the Rice Lake and Sturgeon Lake ecosystems and for the use of land and water resources in the Kawartha Lakes region in general. A list of all reports in the R/S Tech. Rep. series is as follows:

1. Hutchinson N.J., B.J. Clark,, J.R. Munro and B.P. Neary 1993. Hydrological data for the watersheds of Rice Lake and Sturgeon Lake.1986 - 1989, 100 pp.

2. Hutchinson N.J., J.R. Munro, B.J. Clark and B.P. Neary. 1993. Water chemistry data for Rice Lake, Sturgeon Lake and their respective catchments. 1986-1989, 169 pp.

3. Hutchinson N.J., B.P. Neary, B.J. Clark and J.R. Munro 1993. Nutrient Budget data for the watersheds of Rice Lake and Sturgeon Lake. 120 pp.

4. Ryback, M. and I. Rybak. 1993. Sediment pigment stratigraphy as evidence of long term changes in primary productivity of Sturgeon and Rice Lakes (Kawartha Lakes). 24 pp.

5. Nicholls, K.H., M.F.P. Michalski and W. Gibson. 1993. Trophic interactions in Rice Lake I: An experimental demonstration of effects on water quality.

6. Limnos Ltd. 1993. Partitioning of phosphorus in *Potamogeton crispus*. 22 pp.

7. Limnos Ltd. 1993. Rice Lake macrophytes: distribution, composition, biomass, tissue nutrient content and ecological significance. 123 pp.

8. Beak Consultants Ltd. 1993. Release of phosphorus from Rice Lake sediments. 31 pp .

9. Limnos Ltd., Michael Michalski Associates and D.J. McQueen. 1993. Trophic interactions in Rice Lake II. Young-of-the-year yellow perch - *Daphnia* interactions, preliminary findings. 101 pp.

10. Badgery, J.E., D.J. McQueen, K.H. Nicholls and P.R.H. Schaap. 1993. Trophic interactions in Rice Lake III: Potential for biomanipulation. 1988 and 1989 .

11. Standke, S. 1993. The zooplankton of Rice Lake and Sturgeon Lakes, 1986-1988, Kawartha Lakes, Ontario .

12. Nicholls, K.H. 1993. The phytoplankton- water quality relationships of the Kawartha Lakes, 1972-1989.

13. Hutchinson, N.J., K.H. Nicholls and S.H. Maude, 1993. Rice and Sturgeon Lake Nutrient Budget Study: Summary and recommendations.

DISCLAIMER

This report was prepared for the Ontario Ministry of Environment and Energy as part of the Rice and Sturgeon Lakes Nutrient Budget Study. The views and ideas expressed in this report are those of the authors and do not necessarily reflect the views and policies of the Ontario Ministry of Environment and Energy. The mention of trade names and products does not constitute endorsement or recommendation of their use.

ABSTRACT

The distribution and biomass of curly-leaf pondweed (Potamogeton crispus) was similar in both 1986 and 1987 in Rice Lake, covering about 5.6×10^3 hectares or 60% of the lake surface area. The average fresh mass of P. crispus was 1.6×10^3 g/m^2 and the estimated total dry mass of this plant in Rice Lake was 8.2×10^3 metric tons. The total tissue-bound phosphorus, nitrogen and potassium resources were determined to be 12, 119 and 150 metric tons, respectively. There is some evidence that the tissue phosphorus content of curly-leaf pondweed in Rice Lake has declined since 1972 when similar measurements were made. The distribution of curly-leaf pondweed in Rice Lake appears to be regulated by light penetration; growth occurs at depths up to 3.75 metres. Reproduction of this plant is mainly by production of winter buds or turions that fall to the sediment when the plant stops growing and collapses in mid- to late June. Turion densities as high as 2000 per m^2 were found in Rice Lake. After the collapse of the P. crispus population, other aquatic plant species dominated by milfoil (Myriophyllum spicatum) populated the lake. Milfoil was restricted to areas of the lake with water depths of less than two metres and covered a total area of about 1350 hectares in 1986.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS i

SUMMARY OF FINDINGS ii

RECOMMENDATIONS v

LIST OF TABLES vi

LIST OF FIGURES vii

1. INTRODUCTION 1

   1.1 BACKGROUND 1

   1.2 OBJECTIVES 3

2. METHODOLOGY 6

   2.1 MACROPHYTE DISTRIBUTION AND COMPOSITION 6

   2.2 MACROPHYTE BIOMASS 9

   2.3 MACROPHYTE TISSUE NUTRIENTS 11

3. RESULTS 13

   3.1 POTAMOGETON CRISPUS 13

   3.1.1 Distribution 13

   3.1.2 Biomass 19

   3.1.3 Tissue Nutrients 21

   3.2 MYRIOPHYLLUM SPICATUM 22

   3.2.1 Distribution 22

   3.2.2 Biomass 27

   3.2.3 Tissue Nutrients 28

TABLE OF CONTENTS (cont'd)

3.3 MIXED COMMUNITY 29

3.3.1 Distribution 29

3.3.2 Biomass 30

3.3.3 Tissue Nutrients 31

3.4 FLORA OF RICE LAKE 32

4. ECOLOGY OF POTAMOGETON CRISPUS 33

4.1 LIFE HISTORY OF POTAMOGETON CRISPUS 33

4.2 THE EFFECT OF LIGHT AVAILABILITY ON THE GROWTH OF POTAMOGETON CRISPUS 37

4.3 NUTRIENT SOURCES OF POTAMOGETON CRISPUS 47

4.4 ASSOCIATION OF FISH LARVAE AND ZOOPLANKTON WITH POTAMOGETON CRISPUS 55

4.5 TURION DISTRIBUTION STUDY 63

5. CONCLUSIONS AND DISCUSSION 70

5.1 TOTAL MACROPHYTE BIOMASS AND CONTRIBUTED NUTRIENTS TO RICE LAKE ECOSYSTEM 70

5.2 A DISCUSSION OF THE WETLANDS OF RICE LAKE 79

6. ADDITIONAL STUDIES 82

6.1 THE PRESENCE OF ACENTRIA NIVEA ON EURASIAN WATERMILFOIL IN RICE LAKE 82

6.2 AN INVESTIGATION INTO RELATIONSHIPS OF WET VOLUME, WET MASS AND DRY MASS WITH ASH FREE DRY MASS FOR VARIOUS AQUATIC PLANT SPECIES 87

7. REFERENCES 10

TABLE OF CONTENTS (cont'd)

8. APPENDICES 104

Appendix A: Potamogeton crispus Distribution Transects, 1987 105

Appendix B: Fathometer Transects, June-July, 1986 106

Appendix C: Potamogeton crispus Biomass Sampling Results, 1987 108

Appendix D: Biomass Sampling Results, June - July, 1986 110

Appendix E: Potamogeton crispus Loss on Ignition and Tissue Nutrient Data, 1987 111

Appendix F: Potamogeton crispus Loss on Ignition and Tissue Nutrient Data, 1986 112

Appendix G: Comparative Tissue Nutrient Analysis Results, 1987 113

Appendix H: Fathometer Transects, September, 1986 114

Appendix I: Biomass Sampling Results, September, 1986 116

Appendix J: Loss on Ignition and Tissue Nutrient Data, MOE, 1984 117

Appendix K: Myriophyllum spicatum - Loss on Ignition and Tissue Nutrient Data, 1986 118

Appendix L: Vallisneria americana Loss on Ignition and Tissue Nutrient Data, 1986 119

Appendix M: Heteranthera dubia Loss on Ignition and Tissue Nutrient Data, 1986 120

Appendix N: Species List of Plants Collected from Rice Lake 121

Appendix O: Site Records of Plant Species from Rice Lake 122

Appendix P: Secchi Depth and Temperature Readings, Rice Lake, 1987 123

ACKNOWLEDGEMENTS

This report concludes two years of field studies on the macrophyte communities of Rice Lake. A number of people assisted the study team during the project and at this time we wish to acknowledge their contributions.

Deborah Metsger of the Botany Department, Royal Ontario Museum provided materials for the plant collection, literature and other herbarium resources. Dr. T. Sawa of the Botany Department, University of Toronto assisted in identification of the *Chara* species. Personal communication with Scott Painter, Canadian Centre for Inland Waters provided insight into a number of issues concerning the Rice Lake Study. The staff of the Canadian Hydrographic Service provided historical data from old fathometer tracings and, Barry Snider of the Ontario Ministry of Natural Resources, Lindsay District provided information on the wetlands of Rice Lake.

We would like to thank Professor P. Powles of Trent University for use of the Faber light traps and for providing insight into the biology of larval fish in the Kawartha Lakes, and Scott Finucan, a graduate student at Trent University for zooplankton and larval fish identification and providing background information on spawning and larval fish activity in Rice Lake. We would also like to thank Pat Devlin for his diving assistance and technical support during the 1987 field season.

SUMMARY OF FINDINGS

1) Curly-leaf pondweed (Potamogeton crispus) covers approximately 5,560 hectares, or 60% of the surface area of Rice Lake at peak growth. Growth occurs in depths up to 3.75 m. Most growth occurs in the western and central basins of the lake where suitable depths and substrates are available.

2) Growth of curly-leaf pondweed is relatively homogeneous and continuous. Large expanses of curly-leaf pondweed develop in open water areas. Milfoil succeeds curly-leaf pondweed where depth is less than 2 m, particularly in sheltered areas, following senescence of curly-leaf pondweed in June.

3) Average wet (fresh) mass of curly-leaf pondweed at peak growth was approximately 1,640 g/m^2. Average wet (fresh) volume was 1950 ml/m^2. Estimated total dry mass of curly-leaf pondweed was estimated to be 8,200 tonnes.

4) Content of phosphorus, nitrogen, and potassium of curly-leaf pondweed was 1.45 mg/g, 14.5 mg/g and 18.3 mg/g, respectively, on a dry mass basis. Organic content was approximately 69%.

5) Total, tissue bound phosphorus resources contained in curly-leaf pondweed at peak growth were estimated to be approximately 12 tonnes. Similarily, total tissue bound nitrogen and potassium resources were estimated to be approximately 119 tonnes and 150 tonnes, respectively.

6) Total phosphorus resources contained in curly-leaf pondweed were estimated to be 62.3 tonnes in 1986. This estimate is believed to be inaccurate as the estimate was based on results of plant tissue analysis that indicated unreasonably high phosphorus content. The 1987 estimate of 12 tonnes is believed to be more accurate as nutrient content analyses of plant samples used to develop the estimate were verified by an independent laboratories, and were similar to results obtained in previous studies. The biomass and distribution of the curly-leaf pondweed crop was similar in 1986 to 1987.

7) Assuming all nutrients from the curly-leaf pondweed crop are released to the water column during senescence, and no uptake of nutrients by other biota occur, concentrations of phosphorus, nitrogen and potassium in the water column would be anticipated to increase by 0.048 mg/l, 0.48 mg/l, and 0.60 mg/l, respectively.

8) Between early May and mid - September, total, net phosphorus, nitrogen and potassium resources released from macrophytes was estimated to be 11.1 tonnes, 114 tonnes and 147 tonnes, respectively. Contributions of nutrients from curly-leaf pondweed comprise the majority of released nutrients.

9) Reproduction of curly-leaf pondweed is mainly by vegetative turions. High densities of turions (greater than 2,000 per m^2) were found in sediments in areas supporting heavy growth. Low numbers of turions (between 50 and 100 per m^2) were recovered from sediments in areas too

deep to support curly-leaf pondweed.

10) A study to determine the potential shading effect of a spring algae bloom on development of curly-leaf pondweed was inconclusive. While light availability is assumed to limit growth of curly-leaf pondweed to depths less than 3.75 m, it is not known at what period in the year that light availability restricts colonization of deeper waters.

11) A study to determine whether curly-leaf pondweed can obtain required growth nutrients from the water column was inconclusive.

12) A preliminary light trapping study indicated that zooplankton were associated with curly-leaf pondweed more than open water areas. Photopositive fish larvae (yellow perch and white sucker) were more associated with open water areas than curly-leaf pondweed habitat. No larval walleye were captured during the study.

13) Germination of turions occurs in the late summer and fall, and healthy growth of curly-leaf pondweed is present under the ice in late winter in areas supporting growth in the spring. Plants averaged 20 cm tall during late winter. Plant growth is rapid following ice out in response to increased light availability and rising water tempertures.

14) Historical data indicates that phosphorus content of curly-leaf pondweed has decreased since 1972. Nitrogen content has also decreased, but to a lesser degree, since 1972. The N:P ratio has increased from approximately 5 to 10 in the same time interval.

15) Other common macrophytes present in Rice Lake include milfoil (*Myriophyllum spicatum*), tapegrass (*Vallisneria americana*), water stargrass (*Heteranthera dubia*), Canada waterweed (*Elodea canadensis*), muskgrass (*Chara vulgaris*) and bushy pondweed (*Najas flexilis*). Fourteen species of submerged macrophytes were collected during both field seasons.

16) Milfoil was the most abundant macrophyte in Rice Lake following senescense of curly-leaf pondweed in June of both years. In 1986, coverage was estimated to be 1,350 hectares, or 15% of lake area. The majority of milfoil growth was restricted to water depths less than 2 m. Heaviest growth of milfoil occurred in sheltered bays. Some reduction in biomass and distribution occurred from early summer to fall.

17) Total biomass of milfoil on a dry basis at peak crop was estimated to be 1,340 tonnes. Average wet (fresh) mass declined from approximately 800 g/m^2 in early summer to 600 g/m^2 in the fall, during 1986. Milfoil biomass on a unit area basis in Rice Lake was moderate in comparison to milfoil biomass documented previously in other Kawartha lakes.

18) The larvae of the aquatic moth caterpillar, *Acentria nivea*, was observed in 1987 to be causing significant damage to apical tips of milfoil. In some areas of the lake, 85% of tips examined had been damaged. Damage was by grazing of leaves and by boring in the stem. Up to three larvae were found on some tips.

19) Incidence of moth larvae damage on other macrophyte species was not commonly observed. No damage was noted on curly-leaf pondweed, though

damaged milfoil often grew admist curly-leaf pondweed. Minor damage was noted on coontail (Ceratophyllum demersum) and tapegrass (Vallisneria americana), though no larvae were recovered on these species.

20) Growth of various macrophyte species including tapegrass, water stargrass, Canada waterweed and bushy pondweed developed as a mixed community in waters less than 1.5 m. Average wet (fresh) mass was 1,370 g/m^2. Total coverage of the mixed community was estimated to be 350 hectares in 1986.

21) In areas where water clarity was enhanced by incoming river water, growth of mixed community species was heavier and extended into deeper water than in areas of normal water clarity. Reduction of summer algae blooms would increase light availability for submerged macrophytes, and it is anticpated that the biomass and distribution of the mixed community could be significantly increased if water clarity was improved.

22) The dominant wetland community in Rice Lake is the cattail marsh. It is mostly homogeneous, occupies 6% of the lake area and contains a diverse flora. The species composition of the cattail marsh community was documented and collections made of most of the species.

RECOMMENDATIONS

1) Though light availability is presumed tc limit growth of curly-leaf pondweed to depths less than 3.75 m, the time of the year when light becomes the limiting factor is not known at this time. It is recommended that additional light availability studies be conducted to determine when light limits depth distribution. This information will allow researchers to determine what conditions could result in expansion or reduction of curly-leaf pondweed beds.

2) Preliminary studies were conducted in 1987 to investigate the importance of curly-leaf pondweed beds as habitat for zooplankton and photopositive fish larvae. It is recommended that a comperhensive light trapping study be conducted in 1988 with the following objectives:

    i) Determine importance of curly-leaf pondweed growth as habitat for zooplankton and larval fish.

    ii) Document development of zooplankton populations from early spring to early summer and concurrent changes in water clarity.

    iii) Investigate effect, if any, of larval fish predation on zooplankton populations during the spring period and continue until YOY fish become photonegative.

3) Significant infestation of milfoil by the larvae of the moth caterpillar, *Acentria nivea*, was noted in 1987. Though not specifically investigated, milfoil growth in Rice Lake is believed to have diminished between 1986 and 1987, possibly as a result of grazing damage by the moth larvae. It is recommended that an early summer and fall survey of milfoil be completed in 1988 and results compared to 1986 results to determine if significant reduction of milfoil has occurred in the interim.

LIST OF TABLES

Table 1. Macrophyte Biomass and Tissue Nutrient Contents, 1986, 1987

Table 2. Light Intensity as Measured as a % of Surface Illumination in Shaded and non-Shaded *Potamogeton crispus* Beds, Open Water Areas and Under Late Summer Conditions

Table 3. Depth Distribution of the Higher Plants of Trout Lake, Wisconsin, with Light Intensities at the Lowest Depth for Each Species as Percentage of the Incident Radiation

Table 4. Results of Tissue Nutrient Analysis of Samples of Transplanted Plants, Tethered Plants and Undisturbed Growth.

Table 5. Results of Light Trapping Inside and Outside *Potamogeton crispus* Beds

Table 6. Turion Distribution Study Results

Table 7. Total Wet Mass, Dry Mass, Ash Free Dry Mass and Contained Nutrients for Major Macrophyte Species and Communities, 1986, 1987

Table 8. Nutrient Content of Curly-leaf Pondweed and Milfoil Expressed as Percentage of Ash Free Dry Mass

Table 9. *Acentria nivea* on Eurasian Watermilfoil in Rice Lake, 1987

Table 10. *Acentria nivea* on Some Common Submerged Macrophytes in Rice Lake, 1987

Table 11. Results of Regression Analysis for Wet Volume, Wet Mass, and Dry Mass vs. Ash Free Dry Mass

LIST OF FIGURES

Figure 1. Macrophyte Survey Field Work and Methodology

Figure 2. Spring Survey Transects, 1986, 1987

Figure 3. *Potamogeton crispus* Distribution

Figure 4a. Echo Tracing of Transect C2 (June 20, 1986)

Figure 4b. Echo Tracing of Transect C2 (June 25, 1986)

Figure 5. Fall Survey Transects

Figure 6. *Myriophyllum spicatum* and Mixed Community Distribution

Figure 7. Location of Light Trapping Sites

Figure 8. Location of Turion Distribution Transects

Figure 9. Relationship Between Wet Volume and Ash Free Dry Mass for *Potamogeton crispus*

Figure 10. Relationship Between Wet Mass and Ash Free Dry Mass for *Potamogeton crispus*

Figure 11. Relationship Between Dry Mass and Ash Free Dry Mass for *Potamogeton crispus*

Figure 12. Relationship Between Wet Volume and Ash Free Dry Mass for *Myriophyllum spicatum*

Figure 13. Relationship Between Wet Mass and Ash Free Dry Mass for *Myriophyllum spicatum*

Figure 14. Relationship Between Dry Mass and Ash Free Dry Mass for *Myriophyllum spicatum*

1. INTRODUCTION

1.1 BACKGROUND

Rice Lake is a eutrophic lake, portions of which support heavy growth of submerged and emergent aquatic macrophytes. The shallow waters (average depth 2.5m) and rich organic bottom sediments provide growing conditions that allow extensive areal coverage and a high density of macrophytes. In addition to supporting heavy primary production, the rate of fish production and fish harvest by anglers have been recognized as being among the highest in the province (MNR, 1986). The important relationship between macrophytes and fish has been previously recognized (MNR, 1980). Aquatic plants provide nursery and spawning areas for fish, as well as shelter for young fish (MNR, 1980). Mature fish utilize aquatic plants for cover and feeding areas. Rice Lake also has extensive wetland areas that provide important habitat for both fish and wildlife.

Rice Lake is similar to other lakes within the Kawartha system in terms of supporting heavy aquatic plant growth under nutrient rich conditions. However, Rice Lake is unique in that the dominant macrophyte is the curly-leaf pondweed (*Potamogeton crispus*). Curly-leaf pondweed quickly becomes established early in the spring once ice cover is gone and develops to cover about 60% of the lake sediment surface. The heavy, early season growth of curly-leaf pondweed probably provides important habitat for a number of warmwater and coolwater fish species. In most years, curly-leaf pondweed matures, decays, and disappears from most of the lake by mid-June.

Since the 1960's, many of the Kawartha Lakes have suffered from a period of excessive growth of the exotic macrophyte, Eurasian watermilfoil

(Myriophyllum spicatum). In some lakes, Eurasian watermilfoil has become the dominant aquatic plant at the expense of native species. In Rice Lake however, curly-leaf pondweed is the dominant macrophyte, and milfoil has never achieved more than secondary importance. Other common species found in the lake include tapegrass (Vallisneria americana), Canada waterweed (Elodea canadensis), muskgrass (Chara sp.), bushy pondweed (Najas flexilis), water stargrass (Heteranthera dubia), sago pondweed (Potamogeton pectinatus) and redhead pondweed (Potamogeton richardsonii).

Thick, extensive growth of curly-leaf pondweed and Eurasian watermilfoil becomes a major impediment to boating during periods of peak growth. However, the sport fishery of Rice Lake has high economic value to the local region, and heavy macrophyte growth is undoubtedly associated with the health of the fishery. It is in the best interest of the local economy to preserve healthy aquatic plant growth and the highly productive fishery.

Given the ecological significance of macrophytes to Rice Lake, there is a major concern that the present status of the aquatic plant community be maintained to provide a continuing role in support of the valuable fishery. Presently, there is no indicaton of impending loss or reduction in macrophytes. However, other aquatic environments have suffered unanticapated losses of macrophytes accompanied by a shift to less valuable fish species and degraded water quality (Hurley et.al., 1986; Hanna, 1984)

1.2 OBJECTIVES

A number of major studies were competed during the course of two field seasons to document and describe distribution, biomass and nutrient resources of predominant macrophyte species and communities occurring in Rice Lake. Additional studies were conducted to provide information on ecological aspects of curly-leaf pondweed and milfoil, and to develop field techniques for macrophyte surveys.

Specific objectives of different studies are detailed below, accompanied by a summary of methodologies employed to fulfill the stated objectives. Three objectives were considered primary and are described first in the following section. Four secondary objectives were also defined and are described following the description of the primary objectives.

Primary Objectives

1) Document distribution of predominant macrophyte species and communities in Rice Lake, with emphasis on distribution of curly-leaf pondweed.

Central to documenting plant distribution and species composition was the use of echo sounding/Loran C technology, which the consultants have used successfully in previous macrophyte and algae studies (Limnos, 1984; 1985). Echo sounding was used to locate submerged macrophyte beds in water of poor clarity and to obtain information on macrophyte distribution and depths various plant species occupy. Loran C was used in conjunction with echo sounding to precisely record the locations of plant growth. Methods of investigation were documented in sufficient detail to allow reproduction of the study techniques.

Plant surveys conducted at different times allowed determination of seasonal trends of species distribution and biomass. Aerial photography provided additional information on areal coverage and species distribution. Aerial photo series taken previously by the

Ministry of the Environment were also reviewed by the consultants. Combined with distribution information obtained by ground truthing, aerial photography enabled total coverage of different species and communities to be estimated.

2) **Develop estimates of total biomass of different macrophyte species and communities, and when combined with tissue nutrient content information, develop estimates of nutrient resources contained within the total macrophyte biomass between spring and fall. Emphasis on determining the amount of nutrient resources contained within the curly-leaf pondweed crop, and potential effects of nutrient recycling by macrophytes on water quality.**

Quantitative methods were used to collect macrophyte samples and describe biomass of predominant species and plant communities. Biomass samples were collected at different times during the growing season to determine seasonal changes in biomass. Additional information as to species composition and depth distribution of aquatic plants was obtained during the course of biomass studies.

Appropriate numbers of samples of different species were submitted for analysis to determine content of phosphorus, nitrogen and potassium. Estimates of nutrient resources contained within the total biomass of macrophytes were developed by species and on a seasonal basis. The potential nutrient flux from curly-leaf pondweed to the lake environment during the annual period of senescence was of particular interest, and potential increases in water column concentrations of phosphorus, nitrogen and potassium resulting from senescence of curly-leaf pondweed were estimated.

3) **Describe fully the ecology and lifecycle of curly-leaf pondweed in Rice Lake. Determine importance of curly-leaf pondweed for internal cycling of nutrients, and assess possible effects on fisheries that could result from loss, reduction or expansion of the growth area of curly-leaf pondweed.**

Studies were conducted during 1987 to determine the effect of reduced light availability caused by increased algae populations on development of curly-leaf pondweed. As well, the source of nutrients for curly-leaf pondweed was studied as a means to further investigate the importance of curly-leaf pondweed in mobilizing phosphorus from sediments.

A minor study was conducted to determine the number and distribution of curly-leaf pondweed turions in lake sediments, importance of turions for reproduction, and to determine whether sediment turion density reflected abundance of mature plants at sediment sampling locations. During March, 1987, an under ice survey of curly-leaf pondweed was conducted to determine height and stem density of the species during winter in order to describe more completely the lifecycle of curly-leaf pondweed.

A preliminary study was conducted to determine the importance of curly-leaf pondweed habitat for larval fish and zooplankton using light trapping techniques.

Secondary Objectives

1) **Investigate abundance of the larvae of the moth caterpillar, Acentria nivea, in Rice Lake and assess potential for impact of the larvae on milfoil and other aquatic plant species.**

Milfoil specimens were collected from various lake regions and examined for larvae of *Acentria nivea*. Damage caused by grazing or boring was identified and documented. Macrophyte species other than milfoil were also examined for damage caused by *Acentria nivea*.

2) **Develop more efficient techniques to collect macrophyte biomass samples and subsequent determination of nutrient resources contained within macrophyte growth.**

Samples of predominant macrophyte species were collected, and the relationship between wet (fresh) volume and ash free dry mass, wet (fresh) mass and ash free dry mass, and dry mass and ash free dry mass determined. Establishment of good correlations between parameters would allow direct calculation of contained nutrient resources. Greater numbers of samples could be collected in the field, increasing confidence in estimates of total biomass.

3) **Describe Rice Lake wetlands and importance of wetlands to the ecology of Rice Lake.**

Assessments of Rice Lake wetlands developed by the Ministry of Natural Resources were reviewed by members of the study team. The flora and type of wetlands were described based on visitations to different wetland areas.

4) **Document the flora of Rice Lake, with particular emphasis on aquatic and wetland species.**

All encountered macrophyte species were collected, identified and documented by a qualified botanist to provide baseline knowledge of occurrence. Herbarium specimens were prepared of collected submerged, floating, emergent macrophytes and other wetland species, and deposited in the botany department herbarium of the Royal Ontario Museum (TRT).

2 METHODOLOGY

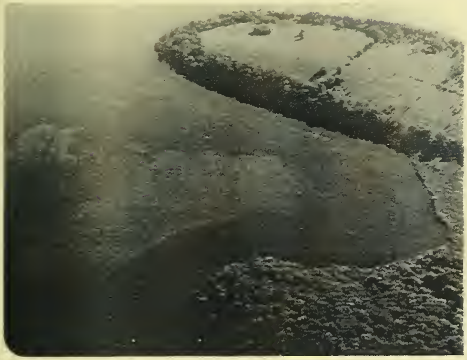
2.1 MACROPHYTE DISTRIBUTION AND COMPOSITION

A survey of the distribution of curly-leaf pondweed in Rice Lake was carried out during June, 1986 and May to June, 1987. The distribution survey of milfoil and the mixed community was carried out during the summer and fall, 1986.

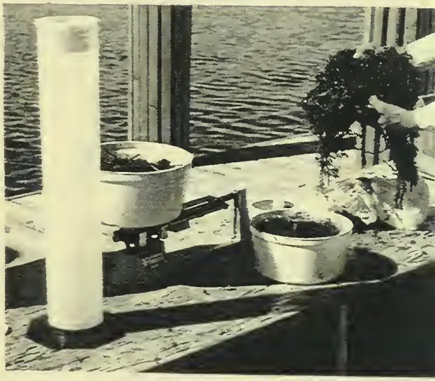
Transects were run using a twenty foot barge powered by a 60 hp outboard motor during the aquatic plant distribution survey. The field crew used a Raytheon Fathometer Chart Recorder to record the water depth as well as the presence, absence and abundance of macrophytes (Figure 1). The fathometer was also useful in indicating the height of macrophyte growth above the bottom and below the surface, and plant density. It was especially beneficial under turbid conditions where visibility was poor.

Raytheon Loran C positioning equipment was used in conjunction with the fathometer to record locational data. Loran C coordinates were recorded on the chart paper the beginning, end and intermediate points of transects. The same Loran C coordinates were recorded onto a transect information sheet, allowing the return to a particular location along the transect for resurvey or biomass sampling. Unfortunately, during the latter part of the 1987 survey, the Loran C malfunctioned and was determined to be unreliable in providing locational data. As a result, compass bearings were used to mark positions along the transect. The barge was operated at a speed of between 0.7 to 1 metres per second which gave the best fathometer performance. The fathometer paper tracings permanently documented the macrophyte growth along the

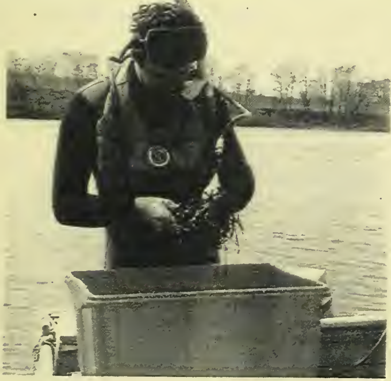
Measuring distribution of macrophytes along a transect using a Raytheon Fathometer.



Aerial photograph of Potamogeton crispus growth, east of Cow Island.



Biomass measurements in the field.



Scuba diver sorts biomass sample for determination of species composition.

Figure 1. Macrophyte Survey Field Work and Methodology.

transect.

During the 1986 survey, all regions of the lake were covered. Transects normally originated and ended at prominent shoreline locations. However, a transect was terminated if macrophyte growth diminished or stopped as the barge moved into deeper waters.

The 1987 survey focussed on field testing the accuracy of the curly-leaf pondweed distribution map generated from the 1986 distribution survey and further documenting areas not fully sampled in the previous survey. New locational transects were run in all regions of the Lake. In addition, spot checks were carried out daily during the survey period to document distribution. Some transects were run through the deep water zone in order to confirm the deep boundary of plant growth.

Species composition was determined by several methods. Macrophytes growing in clear or shallow water could often be identified from the barge. Under conditions of poor water clarity, macrophytes encountered along transect runs were collected by anchor drags and identified. Diver observation at biomass sampling sites and other random sites from around the lake provided species composition, frequency and density information. A collection of submerged, emergent, floating and hydrophytic terrestrial macrophytes was assembled, identified, and then prepared as herbarium specimens.

Previous studies on macrophytes in Rice Lake by the Ministry of the Environment (MOE, 1976) and Ministry of Natural Resources (MNR, 1980) were carried out in August, after the seasonal decline of curly-leaf pondweed. The 1986 summer and fall survey period provided comparable information to the work done by the ministries.

A number of aerial photo sources augmented macrophyte distribution information obtained during field work. Five aerial photo series were taken in 1986 and one in 1987. Four of these series were taken from a private plane using a hand held, 35mm camera and standard, color negative film. Only limited portions of the lake were covered during these flights. Two series, contracted to an aerial survey company, were taken on September 8, 1986 and June 5, 1987, respectively. The former documented the growth of milfoil and the mixed community while the latter covered the peak growth of curly-leaf pondweed. For this survey, a large format, precision survey camera was used, with Aerocolour film.

Two aerial overflights were previously completed by the Ministry of the Environment. On September 15, 1972, an overflight of Rice Lake was completed, and a complete set of stereo images produced. A 70mm camera and conventional, color negative film was used (MOE, 1976). The intention of the aerial photo series taken in September, 1986 was to replicate the 1972 overflight in terms of time and technique, such that a comparison of plant distribution could be made. A second series of photos were taken in June 1983, during the period of maximum curly-leaf pondweed growth. Both of these historical photo series were reviewed by the researchers.

2.2 MACROPHYTE BIOMASS

Biomass sampling was carried out in both the 1986 and 1987 field seasons. The sampling period in June, 1986 and May to June, 1987 focussed on curly-leaf pondweed biomass. The sampling period in early September, 1986 concentrated on milfoil and native species macrophytes such as tapegrass (Vallisneria americana), Canada waterweed (Elodea canadensis), and water stargrass (Heteranthera dubia) that experience peak growth during the late summer and early fall.

In practice, the barge moved to the location where biomass sampling was to occur. A $0.25m^2$ quadrant was cast randomly from the barge and a diver collected all plant material within the quadrant that was above the sediment-water interface. The diver returned the plant sample to the barge for sorting and processing (Figure 1). Three quadrants from each sampling location were amalgamated to form the biomass sample.

After sorting the collected plants by species, the plants were placed into a hand operated Moulinex salad spinner with a basket radius of 7 cm. Twenty hand revolutions in a period of 7 seconds produced a basket rotational speed of 1260 rpm. The centripetal acceleration produced during this period was in excess of 1,270 m/s^2, or 130 times the acceleration produced by gravity. Spinning for a longer time period or repeat spinnings was not found to remove additional water from the sample. The wet mass of the samples was then determined using a triple beam balance. After weighing, the wet volume of the plants was determined by water displacement using a 4000 ml graduated cylinder (Figure 1).

The wet mass, wet volume and species composition of collected macrophytes were entered onto a form prepared for recording biomass information. The water depth, sediment type, Loran C location coordinates, general location and date were also recorded. The collected plants were subsequently air dried and the dry mass of each plant sample determined. However, the 1987 biomass samples were not air dried to determine dry mass.

Biomass sampling locations were typically along pre-run transects where plant growth was known to occur. As well, biomass samples were collected at additional locations where a certain species or plant community was known to grow. At all times, an effort was made to sample at locations within macrophyte beds where growth was representative for a particular species or plant community. As well, macrophyte beds exhibiting heavy growth were purposely sampled to determine an upper limit on biomass for different species or plant communities.

Choosing sampling locations that could be considered representative required subjective judgements on the part of the sampling crew. The large size of Rice Lake dictated that a totally random and comprehensive biomass sampling program was neither feasible nor practical with available personnel. Moreover, the purpose of the biomass information was to combine it with areal coverage information to provide a lake wide estimate of plant biomass and total plant nutrient resources. Providing representative, biomass information that could be applied on a whole lake basis was the objective of the sampling program.

2.3 MACROPHYTE TISSUE NUTRIENTS

During the 1986 and 1987 field seasons, plant samples of curly-leaf pondweed, Eurasian watermilfoil, water stargrass and tapegrass were retained for tissue nutrient analysis. Frozen plant samples were submitted to the Trent Aquatic Research Centre laboratories at Trent University, Peterborough, Ontario. In 1987 split samples of curly-leaf pondweed were sent to Barrenger Magenta laboratories for comparative analysis. The tissue nutrient parameters analyzed for L.O.I (organic content), phosphorus, nitrogen and potassium. The collected plant samples represented the predominant macrophyte species occuring in Rice Lake, and were collected from different areas of the lake.

Potassium content in curly-leaf pondweed was determined as a means of measuring the amount of phosphorus released to the ecosystem when the plants decay. There is minimal demand for potassium by aquatic biota, and accurate measurements of the amount of potassium released by decaying macrophytes should be possible. In contrast, the demand for phosphorus in the aquatic environment is high, and conservative measurements of released phosphorus probably result. By knowing the relative amounts of potassium and phosphorus contained in plant tissues, a more accurate estimate of released phosphorus may be possible by measuring potassium concentrations in the water column during and after the period of decay.

The information obtained will be used to estimate the abundance of these elements in the lake and hence, document the role of macrophytes in contributing nutrients to the lake.

3. RESULTS

3.1 POTAMOGETON CRISPUS

3.1.1 Distribution

Over the two field seasons, a total of 41 transects covering 61 km were run to determine the distribution of curly-leaf pondweed in Rice Lake. The location of the transects is presented in Figure 2. A description of transect locations and the macrophyte species and depth range of plant growth along each transect for 1987 and 1986 surveys is presented in Appendix A and Appendix B, respectively.

The survey work completed in the two field seasons provided valuable information regarding the depth and areal distribution of curly-leaf pondweed. Good water clarity conditions in the spring in 1987 allowed easy observation on the depth distribution of curly-leaf pondweed and other macrophytes in the lake. As a result the fathometer was not used as intensively as it was in late spring, 1986 in determining depth of growth and plant height. Field studies indicated that curly-leaf pondweed beds occupy large expanses of Rice Lake, particularly in the western and middle basins (regions west of Foley Point) where depths and more gently sloping bottoms provide suitable conditions for macrophytes. The lake environment to the east of Foley Point has a greater overall depth than the western or middle basins and therefore limits the distribution of the plant.

Curly-leaf pondweed was observed typically to grow in water between 1 and 3.75m. Shallow growth (1m) was confined to protected bays and shorelines where sediments were suitable. At these depths it formed

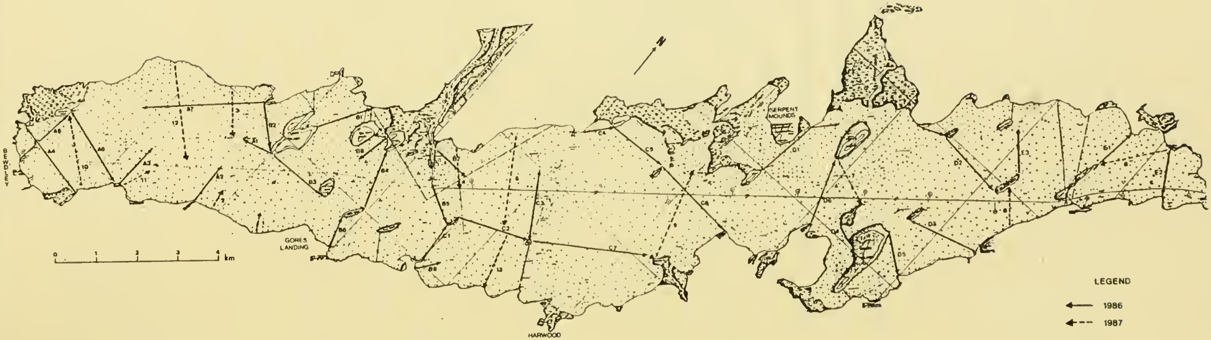


FIGURE 2. SPRING SURVEY TRANSECTS, 1986, 1987

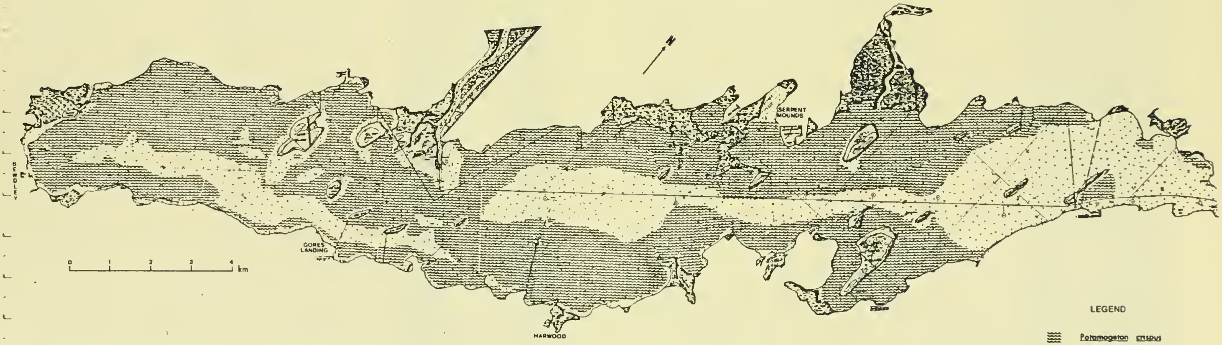


FIGURE 3 POTAMOGETON CRISPUS DISTRIBUTION

luxuriant, monospecific continuous stands. Although uncommon, plants were observed to grow to a depth of 4m. Plants at the 4m depth usually formed discontinuous, patchy stands giving way to sparse growth, while plants at the 1m depth were found to mix with other species such as milfoil, Canada waterweed and water stargrass.

From the 1986 survey, an estimate was made of the areal coverage of curly-leaf pondweed in the lake. A total of 4,200 ha was estimated to be covered by curly-leaf pondweed, representing about 45% of the lake bottom area. It is felt that the distribution survey carried out in 1987 provided a more accurate estimate of curly-leaf pondweed coverage as the survey was done at the time of peak growth in conjunction with an aerial photograph series of the lake. curly-leaf pondweed is estimated to cover 5,558 ha or 60% of the lake bottom. Figure 3 illustrates the areal distribution of curly-leaf pondweed at maximum standing crop in mid-May.

Fathometer tracings revealed that curly-leaf pondweed typically grows about 2.5m tall, however, it was not uncommon to observe plants 3m tall. In waters shallower than 2.5m the tops of the plants would normally reach the surface and flatten out.

A portion of the chart recording from transect C2, running from Spook Island to Tick Island, is presented in Figure 4a. The transect was run on June 20, 1986. It will be noted that the top, thick black line is a surface reflection and the top of this line indicates the water surface. The lake bottom is indicated by the thick dark bottom line. The top of this marking is the sediment-water interface. In this case, curly-leaf pondweed plants are indicated by fine, vertical tracings between the water surface and sediment surface lines.

In figure 4a, curly-leaf pondweed growth is indicated to be about

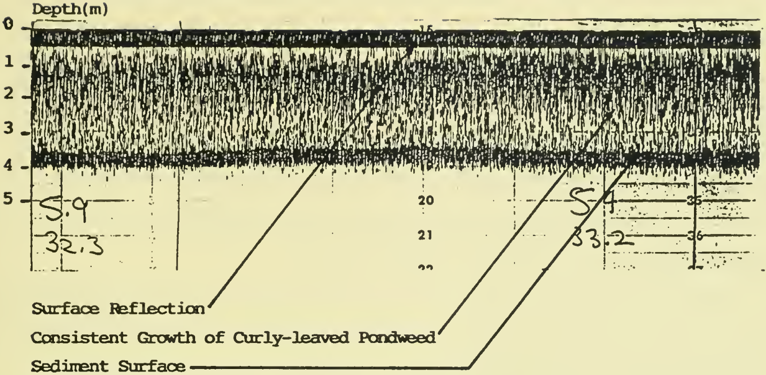


Figure 4a. Echo tracing of Transect C2. Transect run on June 20, 1986, at time of peak growth. Loran C coordinates - 16,005.4; 59,533.2

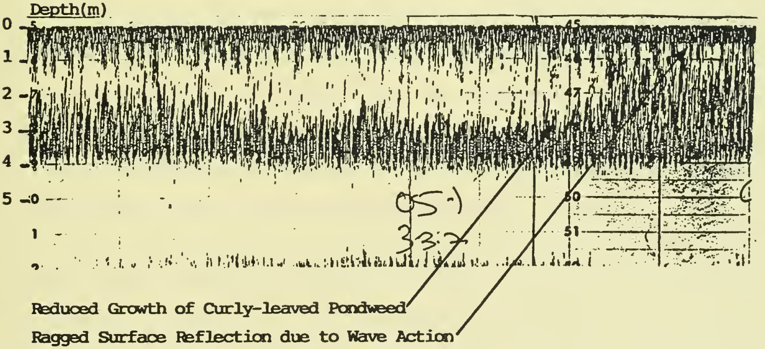


Figure 4b. Echo tracing of Transect C2. Transect run on June 25, 1986, at time of dieback. Loran C coordinates - 16,005.1; 59,533.2

2.5m tall, and the water depth 3.6m. At this point along the transect, the top metre of the water column is largely free of plant growth. The chart recording also indicates that the bulk of leaves occur in the upper half of the plant column, and that stems largely comprise the lower half of the plants. This general habit of curly-leaf pondweed was quite consistent in mature, healthy stands.

Figure 4b is also a section of chart paper from the same transect, run five days later on June 25, 1986. Clearly, the height and density of plants in the water column were markedly reduced in five days. Dieback of curly-leaf pondweed occurs as a result of natural senescence and decay, as well as by physical damage caused by wind and wave action. The location of this portion of transect C2 is exposed to the prevailing northwest wind which would tend to quicken plant reduction. In both figures, Loran C coordinates are indicated. The handwritten numbers are the last digits of the full that were entered onto the chart paper in the field, and the typewritten entries are the full coordinates.

The numerous spot checks made in the 1987 survey verified the depth range of curly-leaf pondweed growth determined from the 1986 survey and also provided more information on areal coverage from specific locations not sampled in the spring of 1986. The area around White Island, Harris Island and the Indian River mouth as observed in the 1987 survey had an extensive dense coverage of curly-leaf pondweed, however, due to the lateness of the survey in 1986, it was not observed at that time. Instead, flourishing milfoil provided dense coverage in those areas at that time.

The 1987 aerial photography provided a clear picture of the macrophyte beds throughout the entire lake. Due to good water clarity at the time of photography, macrophyte growth was easily identifiable over the growth-depth range. The photograph provided information on distribution in areas of the lake that were not sampled in 1986 and was used to map the distribution from the 1987 survey. The photographs provide a record of plant growth which will be valuable for future studies in assessing change in macrophyte distribution (Figure 1).

3.1.2 Biomass

The 1986 biomass sampling program commenced well into the period of curly-leaf pondweed decline and therefore the plant material sampled was not truly representative of the plant beds at peak growth. The 1987 biomass samples were taken at peak growth and were felt to be representative of curly-leaf pondweed growth. A total of 21 biomass samples were collected with an average wet mass of 1,640 g/m^2, occupying a volume of 1950 ml/m^2 (Table 1 and Appendix C). Ten of the 21 samples had both their mass and volume measured while the remaining 11 samples had only their volumes measured. Average volume was 488 $ml/0.25m^2$ which predicted a wet mass of 409.9 g/m^2. It was felt that by knowing the volume an accurate predictive estimate of wet mass could be made. By removing the wet mass measurement step from the methodology an increased number of measurements can be made in the same survey time.

Since curly-leaf pondweed biomass samples were taken well into the period of decline in 1986, the biomass estimate was artificially increased in an attempt to provide an estimate of biomass at peak crop. The 1987 biomass data indicate that the 1986 value was overestimated. The 1986 biomass data for curly-leaf pondweed is presented in Appendix D.

Table 1. Macrophyte Biomass and Tissue Nutrient Content, 1987

Species or Community		Average Wet Mass (g/m^2)	Dry Mass / Wet Mass	Loss On Ignition (%)	P (mg/g)	N (mg/g)	K (mg/g)	N:P
Curly-leaf Pondweed		1640	0.09	68.83	1.45	14.49	18.29	10.0
Milfoil	- summer	800	0.12	74.75	3.25	21.90	2.86	6.7
	- fall	600	0.12	74.75	3.25	21.90	2.86	6.[illegible]
Mixed Community		1300	0.11	70.13	3.78	24.84	7.47	6.5

- milfoil and mixed community N and P values are from MOE (1984).
- all K values except for curly-leaf pondweed are from results obtained in 1986.

3.1.3 Tissue Nutrients

During the 1987 field season, 21 frozen plant samples of curly-leaf pondweed were submitted to Trent University for tissue nutrient analysis (Appendix E). Tissue Nutrient data from 1986 is found in Appendix F. Ten split biomass samples were also sent to Barringer Magenta laboratories for comparative tissue nutrient analysis. The results obtained from both laboratories were similar (Appendix G). The phosphorus value from Barringer was within 0.16 mg/g of the Trent value, nitrogen difference was 0.02 mg/g and potassium difference was a little higher at 4.77 mg/g. The averages of the comparative results were used to calculate estimates of plant nutrient contributions to the lake (Section 5.1). Values obtained from 1986 tissue nutrient analysis seemed to be an order of magnitude different in comparison with 1987 values. Since the 1987 split-sample analysis results were very close, they are felt to be more accurate than the 1986 values. Therefore, the 1986 tissue nutrient values were discarded and not used for total lake nutrient content.

Results of the analysis are presented below:

P = 1.45 mg/g
N = 14.49 mg/g
K = 18.29 mg/g
LOI = 68.83%
N:P = 10

3.2 MYRIOPHYLLUM SPICATUM

3.2.1 Distribution

Milfoil distribution was determined in 1986 and therefore a further survey for milfoil distribution was not necessary in 1987. Figure 2 and Figure 5 indicate the spring and fall survey transects run to determine milfoil distribution. Descriptions of the spring and fall survey transects are found in Appendix B and Appendix H, respectively.

New growth of milfoil was first observed in mid-May growing up through the thick, dense cover of curly-leaf pondweed. At the time of senescence of curly-leaf pondweed, milfoil was growing vigorously and was beginning to form dense stands in areas of suitable habitat that were occupied by curly-leaf pondweed in the spring. During the survey period in May-June 1987 the area around White Island and Rack Island supported very dense growth of curly-leaf pondweed. By mid July, the area was occupied by milfoil (Figure 6).

The heaviest growth of milfoil occurred in waters between 1 and 2m deep. Lake areas that offered shelter from wind and provided suitable depths with unconsolidated sediments promoted thick and monospecific milfoil growth. Waters adjacent to Bewdley, around White and Rack Island, to the east of Curtis Point, the waters in and around the Harris Island wetland complex, Long Island and along the north shore through the Indian River area supported thick milfoil growth. Milfoil was estimated to cover 1400 ha or 15% of the lake in the June survey period.

Milfoil in waters unprotected from wind exposure did not always grow thick or continuously, even if suitable depths or substrates were

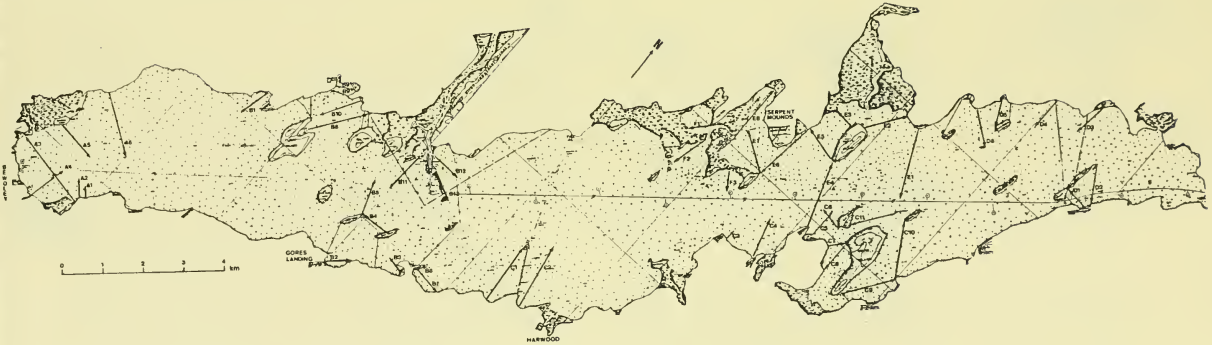


FIGURE 5. FALL SURVEY TRANSECTS 1986

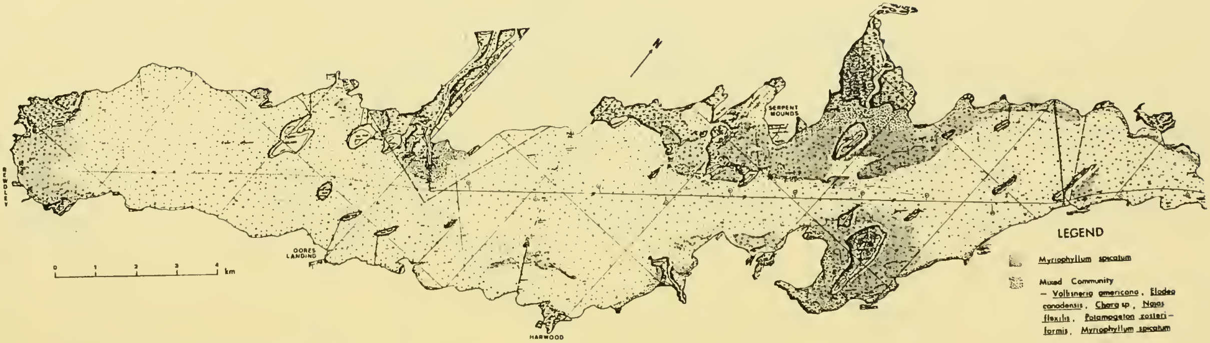

N
SERPENT MOUNDS
BEWDLEY
GORES LANDING
HARWOOD
0
1
2
3
4
km
LEGEND
Myriophyllum spicatum
Mixed Community
– Vallisneria americana, Elodea canadensis, Chara sp, Najas flexilis, Potamogeton zosteriformis, Myriophyllum spicatum

FIGURE 6 MYRIOPHYLLUM SPICATUM AND MIXED COMMUNITY DISTRIBUTION

present. Patchy growth was common, consisting of thick clumps of milfoil surrounded by an empty water column. Often, regions of patchy growth were located at the outside margins of thick growth areas; a plant buffer region between protected waters and exposed main lake waters.

In general, milfoil growth was reduced in vigour and occupied less height in the water column from the spring to the fall survey. Areas that supported thick, topped out milfoil in June had slumping and shortened plants. Some areas, especially those with main lake exposure, appeared to have lost much of the standing crop. Wind damage to exposed beds was significant as observed by windrows of milfoil deposited along shorelines in July. In particular, lake areas near Bewdley and between Long and Cow Island had lost significant areal coverage, but the height and vigour of the plants were significantly reduced. The same trend was replicated around White Island.

During June, the majority of milfoil growth was confined to waters 2m or less. In September, thin, scattered, tall growth of milfoil had developed in deeper waters, with growth noted to 3 m to the west of White Island. In some areas, this spread of deeper growth covered extensive areas. However, the contribution of this growth to the total milfoil biomass was insignificant. Areal coverage of milfoil in September was estimated to be 1,350 ha.

The 1986 professional aerial photograph series taken in September assisted in documenting the distribution of milfoil in the lake. However, due to the annual dense algae coverage at the time of photography a partial resolution obstruction of the plant beds limited use of the series for measurement of areal coverage. Two hand held series in August did not provide total lake coverage but did provide some detail of distribution and density of milfoil growth in different parts of the lake. On August 24, 1987 a visit was made to the area around White Island and Rack Island to observe the status of milfoil growth. This area is known to have extensive milfoil growth and is felt to be representative of milfoil growth under optimum conditions. A number of observations were made which indicated that milfoil status had changed from 1986 to 1987.

In 1986, milfoil growth was thick and abundant with plant beds in many areas reaching the surface and flattening out. Plants were easily observed from the barge and aerial photography recorded the coverage of milfoil growth. In 1987, plant growth was not as easily observable and nowhere in the area did the plants reach the surface. Plant tops however were observed within the top 0.25m of the water column with the lower portion of the plants not visible due to algae density. Secchi depth measurements in 1986 in the White Island vicinity on September 8 was 1.7m whereas, secchi depth in 1987 was 0.6m.

Although no quantitative measurements were made of milfoil biomass, standardized anchor drags were used to indicate general abundance and composition. From 4 sites around White Island it was felt that there was less milfoil biomass in comparison with 1986 and also a significant increase in coontail Ceratophyllum demersum abundance. In 1986 in this area coontail was not observed.

The milfoil plants observed in 1987 were thick-stemmed (0.4 cm diameter) with dense upper foliage growing in patchy clumps compared with the 1986 plants which were not as "bulky" and were a combination of new and old growth.

It is the authors feelings that there was a decline in milfoil biomass and frequency from 1986 to 1987. A concommitant increase in coontail would tend to indicate that a milfoil decline has allowed coontail to increase its presence in this area of the lake.

3.2.2 Biomass

Seven biomass samples of milfoil were collected during the June-July 1986 survey period (table 1). The spun, wet mass of the samples ranged between 351 g/m^2 and 1,284 g/m^2, and averaged 800 g/m^2. Milfoil biomass was highly variable, as a result of the erratic nature of growth displayed by this species. Three major growth types were noted. In protected bays where the waters were less than 2m deep, the growth of milfoil was usually thick and continuous. In waters where depth was beginning to limit milfoil growth, patchy growth was encountered, with the plants growing in thick but isolated clumps. Thin growth was also noted, especially in exposed waters deeper than 2m.

A preliminary attempt was made to develop biomass ranges for the three growth types. The biomass estimate for thick and continuous growth was between 900 and 1200 g/m^2; the estimate for patchy growth between 500 and 900 g/m^2; and for thin growth, between 0 and 500 g/m^2. Although these growth types were observable from the barge, through diver reconnaissance and quadrant sampling, no attempt was made to quantitatively determine the precision of the observations, nor to estimate the areal extent of the different growth types. As a result, the average biomass value of 800 g/m^2 is considered to be the best estimate of milfoil biomass during the late spring - early summer survey period. The mass of air dried plant material averaged 12% of the wet mass.

By September, milfoil vigour had been reduced, and plant height in the water column shortened. The variability of biomass that was noted during the spring period was largely lost by the fall, as areas of thin and patchy growth had been reduced, especially in exposed waters where depth approached or exceeded 2m. New growth of milfoil that may have occurred through late July and August was not observed. Six biomass samples were collected, ranging between 130 and 1,280 g/m^2 on a wet mass basis (Appendix I). The average of the six samples was 600 g/m^2, and serves as the best estimate of fall biomass. The percentage of wet mass to dry mass was the same in September as it was during the spring period, or 12%.

3.2.3 Tissue Nutrients

As mentioned in section 3.1.3, 1986 tissue nutrient values were not used in determination of total lake nutrient content because they were believed to be incorrect. Instead, nitrogen and phosphorus tissue nutrient values for milfoil from MOE 1984 Rice Lake macrophyte tissue nutrient content study were used (Appendix J). These values were felt to be accurate determinations of tissue nutrient content. As well, since the values reflect tissue nutrient concentrations only 2 years previous to 1986, it is felt that no significant changes in tissue nutrient content would be expected to occur from 1984 to 1986. Because potassium concentration was not determined in 1984, potassium values from 1986 will be reported for milfoil samples (Appendix K). The LOI value from 1986 is felt to be accurate and therefore is presented here. The results are presented below:

$P = 3.25$ mg/g

N = 21.90 mg/g

K = 2.86 mg/g

N:P ratio = 6.7

L.O.I. = 74.75%

3.3 MIXED COMMUNITY

3.3.1 Distribution

The mixed community consisted of a number of native macrophyte species growing in close association with each other. Species composition of the mixed community included muskgrass (*Chara* sp.), tapegrass (*Vallisneria americana*), Canada waterweed (*Elodea canadensis*), water stargrass (*Heteranthera dubia*), bushy pondweed (*Najas flexilis*) and milfoil. Most of the growth of the mixed community was confined to 1.5 m or less and usually inhabited inshore, protected areas that offered unconsolidated, level sediments.

The mixed community was found along the southeast shoreline from Bewdley, behind Cow Island, the bay east of Close Point and bays of the Harris Island wetland complex (Figure 6). However, in areas of increased and sustained water clarity, growth of these species, particularly tapegrass, extended into deeper water. This phenomenon was especially noted off the mouth of the Otonabee River, where tapegrass grew extensively into the river "plume" to a depth of 2 m. Profuse growth of the mixed community also occurred near the mouth of the Indian River, where waters also remained clear. An estimated 350 ha, or 4% of the lake area was occupied by the mixed community in September, 1986.

In 1986, the fall survey documented two bays, McGregor Bay and an un-named bay to the north of Harris Island, which had favourable conditions for macrophyte growth but instead, had no macrophytes and exhibited very poor water clarity.

It appeared that the water clarity problem was an effect of sediment suspension (brown), rather than suspended algae (green) which occurs in the lake in the summer and fall. Reports from resort owners and fishermen indicated that in 1985, McGregor Bay supported heavy macrophyte growth throughout the growing season and yet, had become totally devoid of plants from one summer to the next.

A visit was made to McGregor Bay in 1987 during May to see if the water clarity and macrophyte status had changed from the previous fall. Anchor drags and fathometer tracings indicated that macrophyte growth was present, but very sparse with the plants showing poor growth. Main lake secchi depth near Paudash Island on June 2 was 3.5 m and on the same day secchi depth in McGregor Bay was 1.3 m. It would appear that turbid water throughout the growing season presently restricts plant growth in McGregor Bay.

3.3.2 Biomass

Eight biomass samples representing the mixed community were collected between July 3 and September 11, 1986 (Appendix D and Appendix I). Biomass values of 405 g/m^2 to 3,712 g/m^2 were recorded, with an average value of 1,372 g/m^2. Generally, biomass values increased from June to September, reflecting the seasonal development of the mixed community. A biomass value of 1300 g/m^2 is estimated to best represent the biomass of the mixed community during the late summer, early fall period of maximum development.

3.3.3 Tissue Nutrients

Thirteen samples of milfoil, nine samples of tapegrass, and nine samples of water stargrass, as dominant members of the mixed community, were analyzed for nutrient content and loss on ignition in 1986 (Appendix J, Appendix L and Appendix M, respectively). As explained previously, 1984 tissue nutrient values were used instead of 1986 values. By averaging the nutrient contents of the three species, an estimate of the average nutrient content of the mixed community could be obtained. The results of tissue analysis are:

P = 3.87 mg/g
N = 24.84 mg/g
K = 7.47 mg/g
N:P ratio = 6.6
L.O.I. = 70.13%

3.4 FLORA OF RICE LAKE

Thirty five species were collected during the 1986 field season: 14 submerged, 4 emergent, 4 floating and 13 terrestrial (Appendix N). No new collections were made during the 1987 field season, however site records were added to the existing list (Appendix O). All species collected are known to be common to the area. Replicate specimens were collected for each species. The plants were pressed, dried, identified, mounted on herbarium sheets, and labelled. The collection is reposited in the herbarium of the Botany Department, Royal Ontario Museum (TRT). Eight site records were made for those species which were observed but not collected (Appendix O).

Collection emphasis was placed on the submerged, emergent and floating plants found in the lake. The hydrophilic terrestrial species found in the marshes were also collected for documentation of the marsh wetland habitat. Previous reports (MNR, 1980; MOE, 1976) indicate a lesser number of species found in the lake and dealt primarily with only submerged, emergent and floating species. Since the marsh community is the dominant wetland, occupying 6% of the Rice Lake area, it was necessary to collect and document the species composition.

The 1986 survey identified 13 more collected species than during the 1980 study (MNR, 1980) and 24 more than in 1976 (MOE, 1976), though most of these additions were terrestrial species. A number of species found in 1980 (MNR, 1980) were not found during the 1986 field season and these include stonewort (*Nitella sp.*) and leafy pondweed (*Potamogeton epihydrus*).

4. ECOLOGY OF POTAMOGETON CRISPUS

4.1 LIFE HISTORY OF POTAMOGETON CRISPUS

The curly-leaf pondweed, Potamogeton crispus, has greatly expanded its range in North America after being introduced from Europe to the northeastern United States in the the mid-1800's (Tobiessen and Snow, 1984). It was first recorded in Ontario from Ashbridge's Bay, Toronto in 1891 and it has since moved into the lower Great Lakes, including southern Lake Huron, the St. Lawrence River, the Ottawa River system and the Trent and Rideau canal systems (Riley, 1979). It is also found in Quebec and Alberta. It grows in brackish and fresh water and is tolerant of polluted streams and lakes.

In Rice Lake, growth of curly-leaf pondweed is rapid following ice out. Water clarity increases dramatically from ice out until early June, providing the necessary light intensity for growth. On April 24, 1987, the secchi depth measurement was 1.5 m and by the end of May the secchi depth had increased to 4.8 m. Secchi depth readings taken between the end of April and the beginning of June, 1987, are given in Appendix P, along with surface water temperatures recorded during this period. Through late April and early May as the water temperature increases, growth may be as much as 8-10 cm per day in the 10-15^{O}C range (George et al., 1982, in Tobiessen and Snow, 1984). The water was observed to remain clear until July, and it would appear that light availability does not restrict growth of curly-leaf pondweed during this period.

Curly-leaf pondweed maximum biomass was reached by the end of May in Rice Lake. Average wet mass from 1987 studies was estimated to be 1,640 g/m^2 in mature stands (Table 1). The vigour of the plants was observed to change daily once maximum standing crop had been reached and by the middle of June only small scattered patches remained. As the plants senesce they slump to the bottom or are carried by wind and wave action to shorelines. Wind damage contributes to die back especially in main lake areas that are exposed to northwest winds. Curly-leaf pondweed is more readily fragmented than most aquatic vasculars (Engel, 1985) and therefore more susceptible to damage from boat props, strong winds, waves and water currents.

Propagation takes place by sexual and vegetative reproduction. Generally, flowering takes place during the period of maximum day length in June (Engel, 1985). However, a dense crop of curly-leaf pondweed in the bay east of Close Point was found flowering on May 21, 1987. Turions were also found fully developed on these plants. Flowering plants with turions were also observed in other shallow bays around the lake, however, plants growing in water greater than 2m deep were not observed to develop flowers and were slower to develop turions.

Turions are vegetative buds that form on the shoots at the leaf nodes. Initially, they appear as deformed green leaves, but soon shorten and become brittle, resembling a brown pine cone. Two to six turions can develop on a stem (Engel, 1985) and can range from 0.5 to 2.5cm in length. During the period of dieback, the turions sink with the plants and become immersed in the sediments or can be carried with the floating, broken plants (Sculthorpe, 1967).

Although the production of seeds aids in propagation and in-lake dispersal, turions produce the majority of new plant growth (Sastroutomo, 1981). Large numbers of turions were noted to occur in the bottom sediments of Rice Lake (Section 4.5). Turions germinate in late August or September, producing a rhizome and one or more green shoots. In August 1986, germinated turions were observed floating on the water surface. Many germinated turions had little rhizome growth while others had definite rhizome growth as well as leaf and stem development. The germinated turions were few in number compared to the non-germinated turions. In September 1986, growth of new plants up to 0.5m tall was noted in water less than 2m deep. These plants were observed to originate from turions, and were rooted to the bottom by rhizomes.

To document the status of curly-leaf pondweed growth during the winter, below ice observations were made on March 17, 1987. Observations through augered holes in the ice indicated a uniform cover of plants. Of the three sites only two had depths that supported plant growth (2.5 and 2.75 m). No plants were observed at the 5.5 m depth. The water clarity was good; plants could be seen at a depth of 2.75 m. An Ekman dredge was used to collect plants as well as provide quantification of stem density. The two sites with plant growth had plants which were 25 and 18 cm tall with an average of 17 and 16 plants per dredge, respectively. This represents a density of 325 stems/m^2 which is similar to stem density found in the spring at peak biomass (320 stems/m^2 in a representative biomass sample). All plants were formed from turions and had developed extensive horizontal rhizome growth.

Some growth may occur through the winter, depending on the amount of light penetrating the ice and reaching the water column. Minimal snow cover on the ice, or an early spring break-up, contribute to producing a larger biomass than is found in normal years (Engel, 1985). This was observed by a resort owner on Rice Lake who indicated that in a previous winter, under clear ice conditions, the tops of the plants were in contact with the bottom of the ice cover.

To understand the importance and role of curly-leaf pondweed in the ecology of Rice Lake, a number of specific studies were conducted. These are found in the following section and include; effect of light availability on growth of curly-leaf pondweed, importance of curly-leaf pondweed in internal phosporus loading to the lake, turion distribution in lake sediments as an indicator of growth status, and importance as

4.2 THE EFFECT OF LIGHT AVAILABILITY ON THE GROWTH OF POTAMOGETON CRISPUS

Introduction

Light intensity is one factor that determines growth and distribution of macrophytes in a lake. The intensity of light at different depths in the water column can be a function of suspended solids, dissolved organics, phytoplankton, and plant foliage. Phytoplankton densities have been observed to create a shading effect that inhibits growth of macrophytes, reducing their distribution and biomass (Jones et al., 1983). A loss of macrophytes resulting from decreased light availability could have a major impact on lake ecosystems.

At present, no significant blooms of algae develop during the spring in Rice Lake. However, it has been recognized that the occurrence of a major algae bloom in the spring could seriously hamper development of curly-leaf pondweed and potentially damage fisheries health that depends directly or indirectly on macrophyte habitat.

Objectives

The objectives of this study was to determine the effect of reduced light availability on the development of curly-leaf pondweed that might occur in the event of a spring algae bloom.

Methods

During the early growing season (early May), two polyethylene Ancoknit shade screens, each 4m x 3m, were submerged 1.75m below the surface. The degree of shading of the screen material was 65% as specified by the manufacturer. The screens were installed approximately 0.25 m above the tops of developing curly-leaf pondweed plants to allow space for growth and held in place by six, bouyant plastic floats that were attached by ropes to concrete anchors.

The screens were positioned horizontally in the water column by adjusting the height of the bouys in the water column. Installation of the screens and follow up adjustments were made by scuba divers. As the plants grew toward the screens, the screens were adjusted by raising the bouys. A 0.75 m long buttoned seam was left at the center of the screen to allow the photometer to be placed under the screen for light intensity measurements. The screens, plant growth, and plant health were inspected weekly by divers. Plant growth under the screens was compared to growth of adjacent, unshaded plants.

A photometer was used to measure light intensity at the different depths in the water column. Photometer readings were taken underneath the screens and through the water column adjacent to the screened plant bed to determine the effect of plant shading on light availability. A deep water station, devoid of plant growth, was established to provide a measurement of light intensity from the surface through the water column into depths which exclude the growth of curly-leaf pondweed. Water depth at the deep water site was approximately 6m.

A second method of determining the effect of light availability on the growth of curly leaf pondweed involved transplanting curly-leaf pondweed to depths that do not support growth; ie. greater than 3.75 m. Healthy, developing curly-leaf pondweed plants including roots were transplanted to the deep water site in three plastic tubs with 30 cm of sediments obtained from a location supporting curly-leaf pondweed growth. Each tub contained approximately 30 stems. Light intensity measurements and observations on plant growth would indicate the ability of the plants to grow at reduced light conditions. Plant growth and health were measured twice weekly by divers. To provide controls, three similar tubs of transplanted curly-leaf pondweed were prepared and placed in a developing bed of curly-leaf pondweed.

Results

The shade screens were installed in 3 m deep water on the east side of Sheep Island. The first screen was installed by May 15, 1987, and the second by May 20, 1987. Both screens remained in the water through most of the growing season, but were removed on different occasions in early June due to severe damage by boat propellers.

Generally, the screens provided a shading effect which inhibited growth of plants under the screens. Seven days after the screens had been installed, most of the shaded plants were less than 2m, while surrounding, unshaded plants were greater than 2m. The plants under the screens did not appear as healthy and robust as the sorrounding plants. Foliage was not as green, especially in the lower leaves. The screens were removed in early June, and at that time the plants were 20 - 30 cm shorter than sorrounding plants and exhibited some browning of the lower leaves.

Measurements of light intensity taken under the screens, adjacent to the screens, and through the water column at the deep water site are given in Table 2. Readings were taken under cloudy and sunny conditions when the lake surface was calm. Readings of light intensity taken on August 25, 1987, when algae blooms were present are also given in Table 2.

Photometer readings from the 1m depth at the deep water site and shaded plant bed (below the screen) were 57.5% and 52% of surface illumination respectively, indicating that the screens did not provide a significant reduction in light availability . A comparison of light intensity measurements between shaded and non-shaded plant beds at the same depths also showed no significant difference in light intensity.

Table 2. Light Intensity as Measured as % of Surface Illumination in Shaded and non-Shaded *Potamogeton crispus* Beds, Open Water Areas and Under Late Summer Conditions

Depth (m)	Open Water Site (%)	Shaded Plants (%)	Non-Shaded Plants (%)	Late Summer Conditions (%)
Surface	100	100	100	100
0.5	76	-	45	36
1.0	57	53	42	8
1.5	39	34	10	2
2.0	28	19	5	1
2.5	23	0.6	1	
3.0	20			
3.5	16			
4.0	11			
4.5	9			
5.0	6			
5.5	5			
6.0	0.2			

Readings taken at 2.5 m in plant beds under shaded and nonshaded conditions indicate significant shading by the plants themselves, when compared to readings taken at the same depth at the open water site.

Transplanting of curly-leaf pondweed to the deep water site was completed by May 7, 1987. Within ten days of being installed, the deep water transplants had fallen over the side of the tubs, had scenescing brown leaves, and only the top 10 cm of the plants remained a healthy green. While the light intensity at this depth was less than 5% of the the surface illumination, the control transplants in shallow, illuminated waters also developed poorly, indicating that the poor health of the deep water transplants was not soley attributable to light availability, but to transplant stress as well.

Discussion

No significant reduction in light availability was achieved by shading curly-leaf pondweed with screening. As well, the apparent stress of transplanting indicates that failure of plants moved to deep water sites cannot soley be attributable to light deficiency. Subsequently, the experiment was unsuccessful in replicating conditions of light availability that could result from a spring algae bloom.

A reduction of plant growth and vigour was observed, however, for plants under the screen covers. Visually, the screening provided continual shading which was apparent on sunny days. A significant amount of the measured light under the screening probably originated from outside of the screen perimeter, and scattered horizontally to the water column underneath the screening. Use of side screens would have reduced non-incident light although side screens would have hampered observation activity by divers.

Photometer readings taken during late summer indicate the degree of light attenuation that occurs with algae blooms. Light intensity was reduced to 36% of surface illumination at 0.5 m, and to 1% of surface illumination at 2.0 m, during late August (Table 2). Tobiessen and Snow (1984) reported that curly-leaf pondweed can develop in light intensities as little as 1% of surface illumination, indicating that occurrence of a major, spring algae bloom could restrict distribution of curly-leaf pondweed to depths less than 2m. In contrast, during mid May, 1987, 57% of surface illumination was available at 1 m, and 5% of surface illumination at 5.5 m.

In Table 3, light intensities required by other macrophytes are given as observed in Trout Lake, Wisconsin (Wilson, 1941, in

Table 3. Depth Distribution of the Higher Plants of Trout Lake, Wisconsin, with Light Intensities at the Lowest Depth for Each Species as Percentage of the Incident Radiation

Lower limit (m)	% Surface illumination	Species
0.25	62	*Sparganium angustifalium*
		Potamogetan epihydrus
		Ranunculus reptans
		Gratiala aurea f. *pusilla*
		Potamogeton spirillus
		Lobelia dartmanna
		Littorella americana
0.5	45	*Equisetum fluviatile*
		Juncus pelacarpus f. *submersus*
		Eleocharis palustris
		Scirpus acutus
1	25	*Nymphaea adorata*
1.25	22	*Sagittaria cuneata*
1.5	20	*Eleocharis acicularis*
1.75	18	*Potamogetan natans*
2	16	*Ranunculus trichaphyllus*
2.5	14	*Myriophyllum alterniflarum*
		Isoetes macraspora
		Potamogeton pectinatus
3.5	10	*Megalodonta beckii*
		Myriophyllum verticillatum
4	5.9	*Myriophyllum tenellum*
		Sagittaria graminea
4.5	4.5	*Potamogeton gramineus*
		P. praelongus
		Vallisneria americana
		Elodea canadensis
5	3.8	*Potamogetan amplifalius*
		P. richardsonii
5.5	3.1	*Najas flexilis*
6	2.4	*Potamogeton obtusifalius*
		P. berchtoldii (sub *pusillus*)
		P. robbinsii
6.5	1.8	*Ceratophyllum demersum*

Hutchinson, 1975). The table indicates that most of the species found growing at a depth similar to curly-leaved pondweed, have light requirements of at least 2% of surface illumination, indicating that curly-leaf pondweed requires relatively little light for development. Reduction of summer blooms could expand the distribution of native species such as *Vallisneria americana*, *Heteranthera dubia* and *Elodea canadensis* by increasing light availability. These species are presently restricted to depths less than 1.5 m, except in rivermouth areas where water clarity is improved by incoming river flow.

At present, curly-leaf pondweed growth is restricted to water depths less than 3.75 m. Light availablity is presumed to be the limiting factor in terms of depth distribution, as suitable sediments for growth are present in depths greater than 1.75 m, and the depth limit of growth was observed to be consistent in all lake areas. It would seem apparent that curly-leaf pondweed is not limited by light availability during the main growth period in May, but rather during some other point in the lifecycle when water clarity is reduced. Regardless, it is during the spring period that water clarity could be the most drastically affected by algae blooms, and subsequently have the greatest effect on the distribution of curly-leaf pondweed.

It is possible that light becomes limiting in the fall after turions have germinated and stem and leaf growth begins. Turions found at depths greater than 3.75 m (Section 4.5) indicate potential for curly-leaf pondweed to become established at depths greater than 3.75 m. When water clarity is poor in the fall (secchi < 1 m), the turion has nutrient reserves which can support germination and initial plant growth (Rogers and Breen, 1980). However, if the plants are unable to begin photosynthesis before the nutrient reserves in the turions are exhausted, it is unlikely they will survive until the spring when water clarity improves and photosynthesis can be activated.

4.3 NUTRIENT SOURCES OF POTAMOGETON CRISPUS

Introduction

Vascular aquatic plants normally obtain growth nutrients from the sediments. Nutrient recycling from sediments may thus be promoted by macrophyte growth, and recycling by this pathway can be significant when extensive growth of macrophytes occurs in a particular water body. Expansion or reduction of plant growth could affect the amount of nutrient recycling that occurs in a lake, and subsequently increase or reduce the amount of nutrients that are available for other aquatic biota that do not utilize sediment bound nutrients.

Extensive growth of curly-leaf pondweed develops annually in Rice Lake during the spring period. It is believed that nutrients required for growth of curly-leaf pondweed are obtained from lake sediments. There is a possibility, however, that a significant amount of nutrients are obtained from the water column. In that case, the annual crop of curly-leaf pondweed could operate through passive uptake as a temporary store, rather than promoting active uptake and cycling of sediment nutrients. If significant amounts of nutrients are obtained from the water column, an increase or decrease of total, curly-leaf pondweed biomass would have a minimal effect on sediment nutrient recycling.

Objectives

In order to investigate nutrient sources of curly-leaf pondweed, experiments with developing curly-leaf pondweed plants were conducted with the following objectives:

1) To determine whether curly-leaf pondweed can obtain enough required growth nutrients from the water column to support growth.

2) To contribute to concurrent research determining direct release of phosphorus from sediments in order to develop further knowledge of phosphorus recyling in Rice Lake.

Methods

Developing, curly-leaf pondweed plants were transplanted into a sand medium in order to isolate the experimental plants from natural sediments. Approximately thirty developing and intact curly-leaf pondweed plants with roots were collected by divers and transplanted into each of three plastic tubs that were filled with sand to a depth of 20 cm. Care was taken to minimize damage to roots and stems during transplanting. Divers then placed the tubs on the bottom in 2.5 m of water in an area supporting heavy growth of curly-leaf pondweed. Three additional tubs were filled with bottom sediments from the same area of curly-leaf pondweed growth, and similarily planted with curly-leaf pondweed plants to serve as controls. The control tubs were placed adjacent to the experimental tubs on the bottom, and the location of each tub marked with a floating bouy.

The initial height of transplanted plants was recorded at the time of transplanting. Observations as to plant height, condition of health and turion development were subsequently made on a weekly basis by divers. Growth rate of transplanted plants was compared to growth of undisturbed plants in the surrounding area. Failure of plants transplanted to the sand medium would indicate that insufficient uptake of nutrients occurs from the water column to support growth.

A second method employed was to remove developing plants and roots from the sediments and tether the lower stem with an anchor, allowing the plants to float upright in the water column in an unhibited manner. The tethered plants were anchored in water depths supporting good growth of curly-leaf pondweed.

Samples of plants from the sand transplants, the natural sediment transplants and the tethered plants were retained for analysis to determine phosphorus and nitrogen content. Differences in nutrient content between the different treatments was anticipated to indicate degree of uptake of nutrients from the water column or natural sediments.

Results

Transplanting of developing curly-leaf pondweed plants was completed on May 7, 1987. At the time of transplanting, the plants were approximately 1.5 m tall. During the next three weeks, no significant growth was noted of plants in natural sediments or the sand transplants. During this period, surrounding, undisturbed growth developed to approximately 2.5 m. However, the plants transplanted to tubs with natural sediments remained greener and more upright than plants in the sand medium. Senescence of all transplanted plants was exibited by June 1, 1988. Turions developed on transplanted plants sooner than on surrounding, undisturbed plants.

The tethered plants were installed on May 21, 1987, and at this time, were approximately 2.0 m tall. No plant growth was observed after tethering, and turion development occurred prior to senescence soon after the plants were tethered. Senescence of undisturbed plants in the area did not begin until the first week of June. All transplanted and tethered plants were recovered and removed during the first week of June, 1988.

Results of tissue analysis for selected samples of transplanted and tethered plants are presented below. Results of analysis of curly-leaf pondweed retained for lake wide estimates of nutrient resources are also presented below for comparative purposes.

Table 4. Results of Nutrient Analysis of Samples of Transplanted Plants, Tethered Plants and Undisturbed Plant Growth

	LOI (%)	N (mg/g)	P (mg/g)	K (mg/g)
Natural Sediment Transplants	67	12.9	1.03	17.1
Sand Transplants	67	12.9	1.14	14.5
Tethered Plants	59	11.5	0.95	8.3
Undisturbed Curly-Leaf Pondweed	69	14.5	1.45	18.3

Discussion

Poor development of curly-leaf pondweed plants in tubs filled with natural sediments would seem to indicate that transplanting stress significantly affected development of the plants. Damage to the fine root structure of curly-leaf pondweed during transplanting is suspected to have contributed to growth failure. This result obscures the effect of isolating developing plants from natural sediments, making results of the experiment difficult to interpret. Nonetheless, no evidence of nutrient uptake from the water column was exhibited during the study by tethered ortransplanted plants.

Failure of growth does not eliminate the possibility of partial use of solubiized nutrients. Successful growth of tethered plants and plants transplanted to the sand medium would have indicated that curly-leaf pondweed can develop by using nutrients obtained exclusively from the water column. While there may have been some uptake of solubilized nutrients, there was no opportunity to determine the degree to which this occurred. Some nutrients may be more readily obtained from the water column than others. Rogers and Breen (1980) concluded that solubilzed N-NO_3 and potassium were utilized by curly-leaf pondweed though phosphorus was obtained largely from the sediments.

Nitrogen, phosphorus and potassium content of transplanted and tethered plants were similar (Table 4). However, nitrogen, phosphorus and potassium content of experimental plant samples was lower than for analysed samples of undisturbed growth. Gerloff and Krombholtz (1966) reported that minimum nitrogen and phosphorus requirements for growth are 13 mg/L and 1.3 mg/L, respectively. Concentrations of nitrogen and phosphorus in samples of transplanted and tethered plants were below this level. In comparison, samples of undisturbed plants samples were above concentrations of phosphorus and nitrogen considered minimal.

While the number of experimental plant samples analysed was small (n=6), these results would indicate that nutrient deficiency may have contributed to senescence of experimental plants. Significant nutrient loss, however, from the plants to the water column may have occurred prior to collection of samples for analysis.

Use of transplanting techniques to determine whether significant amounts of solubilized nutrients are utilized by curly-leaf pondweed during growth may not be feasible for reasons discussed in this section. Rather, a comperhensive water quality monitoring program initiated following ice break up would document whether concentrations of dissolved nutrients decrease during the main growth phase of curly-leaf pondweed. Combined with water quality information already available for the period following senescence of curly-leaf pondweed, a complete record of fluctuations in concentrations of dissolved nutrients that accompany the development and decline of curly-leaf pondweed would be established.

4.4 ASSOCIATION OF FISH LARVAE AND ZOOPLANKTON WITH POTAMOGETON CRISPUS

In 1987, a study was undertaken to investigate the importance and significance of curly-leaf pondweed to stages of early life history (0+ and 1+ cohorts) of yellow perch and walleye, two of the most important sport fishes in Rice Lake. Early in the field season the study was terminated by the Project Team for financial reasons. Although the study was not completed, preliminary results were obtained, and study methods and preliminary findings are presented below.

Introduction and Objectives

Macrophytes play an important role in providing habitat for fish species. The structure and density of macrophyte beds provide shelter for small fish from larger predators (Aggus and Elliot, 1975 in Gregory and Powles, 1985), cover for large fish and shelter for small invertebrates which are a food source for many fish.

In Rice Lake, early, extensive spring growth of curly-leaf pondweed could be important as potential habitat for newly hatched, larval fish. To determine the importance of curly-leaf pondweed as habitat for fish larvae and zooplankton, a light trapping study was conducted to collect larval fish and zooplankton from areas that support curly-leaf pondweed growth and areas where growth was absent.

Methods

Modified Faber (1981) light traps were used to collect larval fish and zooplankton. One trap was round in cross-section, while the other was square. Fish larvae and zooplankton, attracted by the light source, entered the trap by four adjustable openings. The internal aperatures were set at 3mm (Gregory and Powles, 1985).

Sampling occurred under night conditions between the hours of 10 p.m. and midnight. Sampling locations included weed and non-weed sites in the bay east of the Otonabee River mouth, south of Sheep Island, the north end of Spook Island and the north end of Black Island (Figure 7).

The barge was positioned at the sampling location, anchored to prevent movement, and the light traps put into the water. The traps were suspended from each side of the barge by ropes. Light trapping was carried out in and outside of curly-leaf pondweed beds with the traps set in the water for 15 minutes at each site. The traps were set at depth ranging from the surface to 1 m. The water depth at the non-weed sites ranged from 1.5 to 6m, while the depth of weed sites was consistently 2m. At all non-weed sites trapping was carried out at least 30 m from the edge of the weed bed.

After the prescribed time in the water the traps were pulled and the collected specimens removed. The specimens were placed into a glass jar and preserved in a solution of 5% formalin with sucrose, for later identification and determination of relative abundance. The two different traps were used at each site in an attempt to determine if larval fish and zooplankton were attracted to one over the other. The preserved specimens were identified by Limnos staff using Auer (1982) and Pennak (1953).

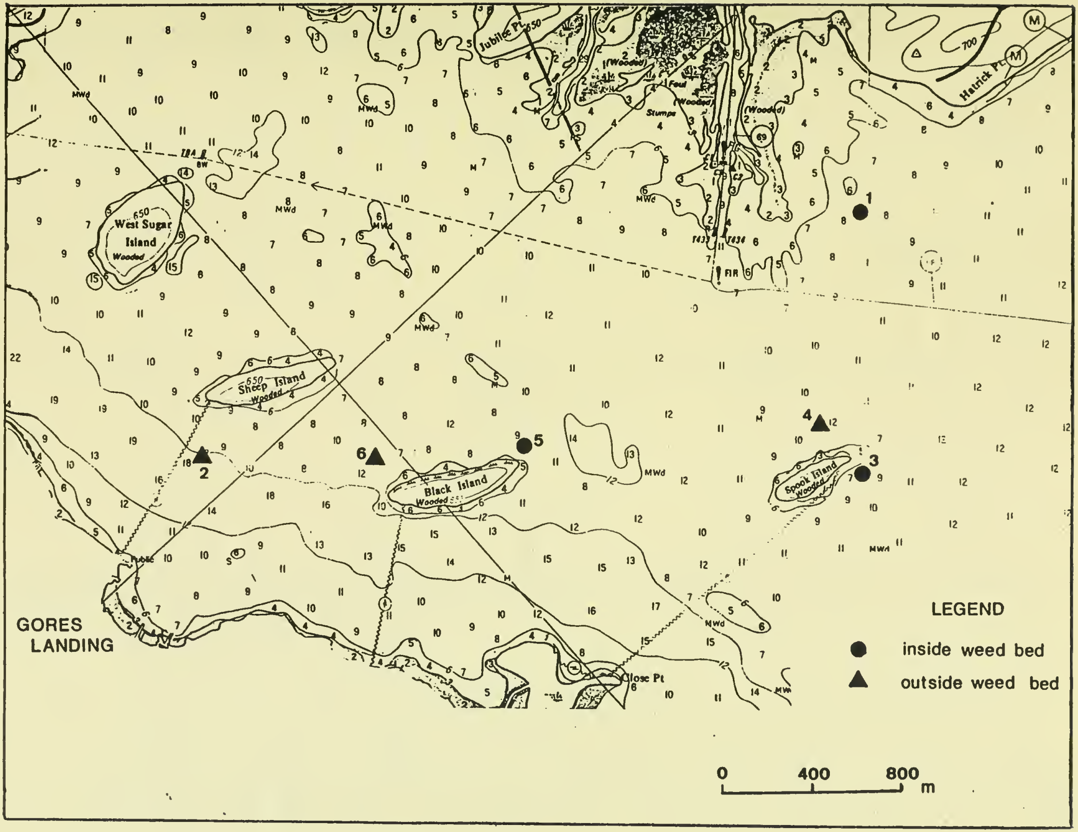


Figure 7. Location of Light Trapping Sites.

Results

Zooplankton and larval fish were observed to be attracted to the light soon after the traps were placed in the water. The number of organisms attracted to the light increased over the next ten minutes, after which time there was no observable increase. At all sites, the number of zooplankton and larval fish which entered the light traps was a small percentage of those that were attracted to the light. On the evening of May 21 at site 4, thousands of larval fish were observed near the surface. However, only several hundred were attracted to the light and of those, only 126 entered the trap. No 1+ cohort fish were captured during the study.

Over a total of 1.5 hours of light trapping, 273 larval fish were captured; 165 yellow perch and 108 white sucker (table 5). Although an equal amount of time was spent light trapping in areas of growth and no growth, there was no difference in the number of larval fish captured (132 in weeds vs. 141 out of weeds). No walleye larvae were captured by light traps from either of the two habitats.

Daphnia (*galatea*, *pulex* and *retrocurva*) was the most abundant zooplankter captured. *Bosmina longirostris* was found at sites 1, 5 and 6 but was only abundant at site 5. Copepods (*Cyclops bicuspidatus* and *Cyclops* sp.) were present in sites 2, 4, 5 and 6 but were a small component of the total capture. Sites 5 and 6 provided the greatest diversity of species caught in the light trap (Table 5). A total of 5 zooplankton taxa and 2 fish species were captured at site 5 and 8 zooplankton taxa and 2 fish species were captured in the light trap at site 6.

Table 5. Results of Light Trapping Inside and Outside of Potamogeton crispus Beds

Date	Location	Site	Depth (m)	Zooplankton Composition (%)	Larval Fish (numbers)	Comments
May 12	Bay East of Mouth of the Otonabee River *	1 in weeds	2.5	Daphnia - 95 Bosmina - 5	-	abundant zooplankton
"	South of Sheep Island	2 out of weeds	5.5	Daphnia - 99 copepod - 1	yellow perch - 1	"
May 21	North End of Spook Island	3 in weeds	2.5	Daphnia - 100	white sucker - 9	zooplankton not abundant
"	"	4 out of weeds	3.6	Daphnia - 99 Gammarus copepod } 1	white sucker - 95 yellow perch - 31	"
"	North End of Black Island	5 in weeds	2.7	Bosmina - 90 Daphnia - 5 Leptodora copepod Hydracarina } 5	yellow perch - 120 white sucker - 3	abundant zooplankton
"	"	6 out of weeds	3.7	Daphnia - 50 Bosmina - 40 copepod - 5 Chaoborus Gammarus Hydracarina Leptodora } 5	yellow perch - 13 white sucker - 1	zooplankton not abundant

* sample from a community of milfoil, Canada waterweed and some curly-leaved pondweed.
* since zooplankton volume or biomass was not measured only relative comparisons can be made between sites.

Discussion

The Faber light traps were successful in attracting photopositive larval yellow perch and white sucker, as well as zooplankton. Generally, more zooplankton was captured in the weed sites than in the non-weed sites. At the Black Island location there was 3 to 4 times more zooplankton captured in the weeds (site 5) than outside of the weeds (site 6). Daphnia was the most common and abundant zooplankton caught, however, from our findings, it is not conclusive that Daphnia prefers to inhabit weed sites more than non-weed sites.

Yellow perch larvae inhabit weedy areas for protection and food resources. The abundant cladocerans captured in the weeds at Black Island are preferred food sources for yellow perch and walleye (Bulkley et al., 1976) and therefore may account for the large numbers of larval perch caught at this site (120). However, at the non-weed site at Black Island (site 6), the opposite effect was observed; zooplankton were not as abundant as in the weed site (site 5) and only 13 yellow perch were captured.

It was anticipated that sampling would attract larval walleye, however, no larval walleye were caught in either weed or non-weed sites. Potter (1980) had difficulty in catching post larval walleye in Rice Lake, during late June to mid - July, using netting and trapping techniques and therefore could not determine if there was an association between 0+ walleye and macrophyte habitat. Only 1 larval fish was captured on May 12. It was expected that more would be captured since larval perch and walleye are photopositive at this time. However, a partially moonlit night probably reduced the effect of the light trap as the single light source and therefore did not provide an attraction to larval fish.

Light trapping proved to be an effective method of attracting and collecting larval fish by utilizing their photopositive reaction to light during the first 4 -6 weeks of post hatch development. Light trapping allows fish collection in weedy areas where conventional trap net and seining techniques are not practical. Light trapping is also an effective method of collecting zooplankton.

A difficulty encountered during the study was the inability to capture most, if not all, of the larval fish attracted to the light. Larval walleye may have been attracted to the light source and remained near the trap, but did not enter. More information on larval fish species and abundance could be obtained if a better trapping structure was used. Use of an underlying net with with the light traps would provide more complete capture. The ability to dim the trap lights through the trapping period would probably encourage more of the attracted fish to enter the trap.

At this time it is unknown if the decline of curly-leaf pondweed has an effect on those zooplankton and larval fish species which inhabit the plant beds. The sudden decline of plant cover could remove the aspect of protection and shelter as well as feeding sites for the larval fish, and protection for zooplankton from predation. It is recommended that a light trapping study be conducted through the period of growth and decline of curly-leaf pondweed to measure any changes in larval fish and zooplankton species and numbers as a result of loss of habitat. As well, such a study may indicate if a loss of zooplankton during the late spring is due to predation by planktivorous fish or by other factors.

A light trapping study conducted from the time of larval hatch into the post larval period would provide an indication of the abundance and composition of larval fish species present in the lake. The study would also record zooplankton abundance, species and seasonal population changes. As noted previously, this study was not funded or fully completed. Nonetheless, the preliminary information indicates that zooplankton are associated with curly-leaf pondweed beds, and larval fish less so. In light of the abundance of curly-leaf pondweed in Rice Lake, it would appear important that a better understanding of the relationship between early life history stages of fish and zooplankton with curly-leaf pondweed be established.

4.5 TURION DISTRIBUTION STUDY

Introduction

Curly-leaf pondweed turions are vegetative propagules that aid in the propagation and dispersal of the species. Flowering and the production of seeds is infrequent, and turions have been identified as the major method of propagation (Engel, 1985; Sastroutomo, 1981). However, flowering was observed in shallow bays in Rice Lake in 1987. Observation during the course of field work indicated that a significant number of turions are produced by the curly-leaf pondweed crop. In August 1986, turions were observed floating on the water surface, and disturbing of the bottom sediments, in some locations, released large numbers of turions that rose to the surface.

During September 1986 a study was conducted to investigate the importance of turions to the life cycle of curly-leaf pondweed. Turion densities in the bottom sediments were determined by sediment sampling. It was anticipated that sediment turion density would reflect the degree of growth of mature curly-leaf pondweed at sample locations. It is hypothesized that sediment turion densities may be useful in the future to indicate whether the growth of curly-leaf pondweed is increasing or decreasing.

Objectives

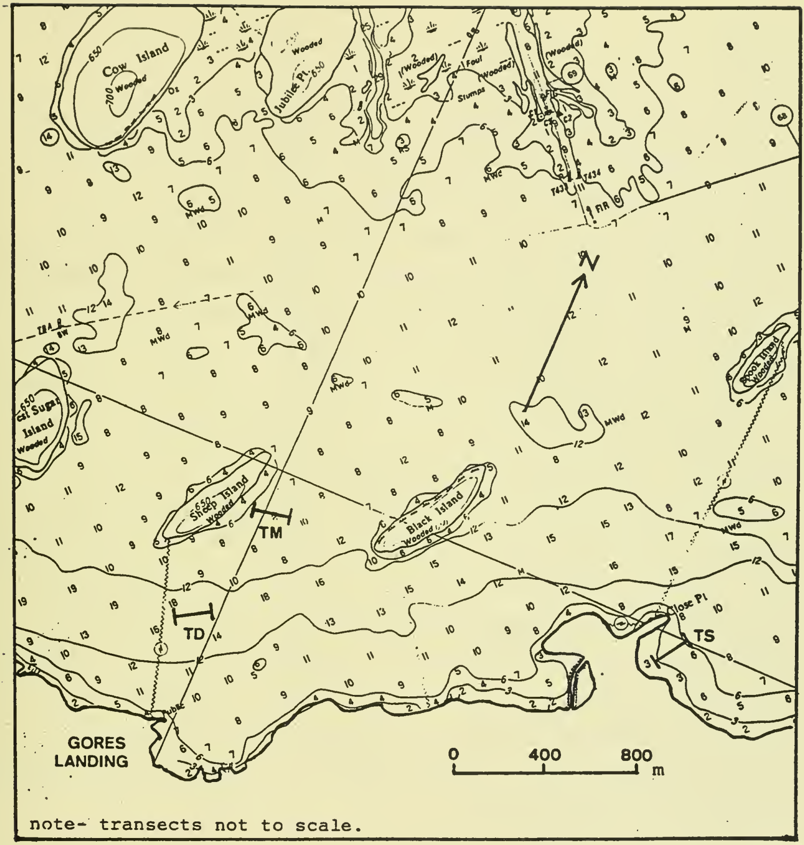
The objectives of this study was to document the density of turions in lake sediments at different depths, and to determine whether sediment turion density at sediment sampling locations reflected abundance of curly-leaf pondweed in that area.

Methods

Three transects were located at depths that were within and outside the range of curly-leaf pondweed growth. Each transect was approximately 60 m long, and five samples were taken at 15 m intervals along the transect. The samples were colleted with a $0.052m^2$ Ekman dredge on September 15, 1986. The samples were put into a wire mesh screen box and seived to remove sediment particles but retain the turions. The turions were counted and and stored in plastic bags. The fathometer was used to record water depths along the transect, and Loran C coordinates were recorded at the ends of each transect.

Figure 7 shows the location of the transects. Transect TS was located in an embayment to the east of Close Point, and water depths along the transect ranged from 0.9 to 1.5m. Transect TM was located to the east of Sheep Island in the vicinity of the limnocorral site, in waters 2.1 to 2.2 m deep. Transect TD was located in water 5.7 m deep, between Gores Landing and Sheep Island.

The transects were purposely located in areas and water depths that supported varying amounts of curly-leaf pondweed growth in the spring. The area near Sheep Island where transect TM was located supported continuous and monospecific growth of curly-leaf pondweed growth in June. Transect TD was located in water that was observed to be too deep for curly-leaf pondweed growth, and transect TS was located in waters too shallow for optimal growth of curly-leaf pondweed.



note- transects not to scale.

Figure 8. Location of turion distribution transects.

Results

Table 6 indicates the number of turions collected from each dredge along the transects. Transect TS had an average of 70.8 turions per dredge (1361.5 turions/m^2). The embayment, where the transect was located, was shallow and the growth observed was that of the mixed community; coontail, milfoil, waterweed, water stargrass and muskgrass. But, during peak growth of curly-leaf pondweed in 1987, the transect location had a very dense coverage of pondweed. A small percentage of the turions had germinated, having stems 30 cm tall with 5 to 8 leaves.

Transect TM had an average of 122.8 turions per dredge (2365 turions/m^2). This transect was in an area that supported heavy curly-leaf pondweed growth in the spring. Some of the turions had rhizomes, but few had shoots. Those with shoots were less than 12.5 cm tall. Transect TD had an average of 3.6 turions per dredge (69.2 turions/m^2). The water depth along transect TD was 5.7m, a depth observed to be too deep for curly-leaf pondweed growth. The transect was located in a channel of deeper water about 0.5 km wide, and according to previous fathometer readings was devoid of plants. Although the number of turions found was low, at least half of them had rhizome and shoot development.

Table 6. Turion Distribution Study Results

Transect	General Location	Sample Point	Number of Turions Per Dredge	Average Number of Turions Per Dredge	Average Number of Turions per m^2
TS (0.9 to 1.5m)	Bay east of Close Point	1	23	70.8	1361.5
		2	46		
		3	161		
		4	69		
		5	55		
TM (2.1 to 2.2m)	East of Sheep Island	1	131	122.8	2361.5
		2	170		
		3	102		
		4	104		
		5	107		
TD (5.7m)	Between Gores Landing and Sheep Island	1	2	3.6	69.2
		2	3		
		3	2		
		4	5		
		5	6		

Discussion

Transect TS covers a depth of water which supports curly-leaf pondweed growth. Due to shallow depths the plants reach the surface, flatten out and do not attain the height, and perhaps biomass, of plants at greater depths. In 1987, curly-leaf pondweed in this area did not form a monospecific stand but instead, was the dominant species in association with milfoil and Canada waterweed. The less than optimal growth conditions for curly-leaf pondweed in this bay and the abundance of other macrophytes may account for the smaller number of turions in comparison with the larger number of turions recovered along transect TM.

Turions were most numerous in sediment samples collected along transect TM. This result was not unexpected, as heavy growth of curly-leaf pondweed occurred in the area of the transect during June. The depth of the water along the transect (2.1 - 2.2m) was observed to support heavy and monospecific growth of curly-leaf pondweed in most lake areas with that depth.

The few turions found along transect TD was indicative of the negligible plant growth in the deep waters. The turions probably represent the dispersal from adjacent stands in shallower water.

The authors noted that after storms, germinated and non-germinated turions were observed floating on the water surface. The turions were mostly scattered but did congregate in the lee of islands where no wind, wave and water current activity was present. Given the unconsolidated nature of the sediments, and relatively shallow water in areas of high turion density, heavy winds may be capable of disturbing the sediments enough to allow the release of immersed turions. However, the turions observed floating were a very small fraction of those found in the sediments.

It is evident that the number of turions is an indicator of abundance of curly-leaf pondweed standing crop. Though turion density can not be used to quantitatively describe the biomass of the standing crop, a qualitative relationship appears to exist between turion density and standing crop biomass or stem density. A decline or increase in the standing crop might be reflected by the number of turions contained in the sediments in a particular area. The turions could be used as indicators of change in standing crop biomass or stem density from year to year, as well as a predictive measurement of growth trends for future years.

Nutrient analysis of turions indicated that phosphorus content was 3.2 mg/g on a dry weight basis which is double the phosphorus content in the plants (1.45 mg/g). The nitrogen and organic content of turions are similar to that found in the plant tissue (15 mg/g and 62.3%, respectively). This is a reflection of nutrients available to the plant which are translocated to the turion and do not indicate the total chemical energy reserves stored in the turion.

Turions are easy to collect and can be gathered in large numbers from areas where there is a large standing crop in the spring. Artificial dormancy breaking and germination can be induced under natural or laboratory conditions. Where the presence of this species was deemed to be beneficial, and water quality, light, sediment, and depth characteristics suitable for growth were available, curly-leaf pondweed would be an easy species to introduce and propagate.

5. CONCLUSIONS AND DISCUSSION

5.1 Total Macrophyte Biomass and Tissue Nutrients in Rice Lake

The role of macrophytes in the ecology of Rice Lake was investigated during the 1986 and 1987 field seasons. Emphasis was placed on the dominant macrophyte in the lake, curly-leaf pondweed (Potamogeton crispus), due to its extensive coverage and abundance. Eurasian watermilfoil (Myriophyllum spicatum) and the mixed community, although not as abundant, were also investigated since they provide the remainder of macrophyte coverage and biomass in the lake.

On the basis of information obtained during the two field seasons, estimates of phosphorus, nitrogen and potassium contained within the total macrophyte biomass were developed. Combining biomass information with areal distribution information, and the nutrient and ash contents of the major macrophyte species and communities, allow an estimation of total, tissue bound nutrients.

Total phosphorus resources contained in curly-leaf pondweed was estimated to be 62.3 tonnes in 1986, significantly different from the 1987 estimate of 11.9 tonnes. The 1986 estimate was based on laboratory analysis indicating phosphorus content of curly-leaf pondweed to be 17.4 mg/g, on an ash free basis. In 1987, samples of curly-leaf pondweed were submitted to two laboratories for independent analysis. Results of analysis from the two laboratories were similar, and indicated an average phosphorus content of curly-leaf pondweed to be 2.1 mg/g, on an ash free basis. This determination of phosphorus content is also similar to results obtained in previous studies of macrophytes in Rice

Lake (MOE, 1984).

It is assumed, therefore, that the 1986 analysis results may have been unreasonably high, resulting in an overestimation of total phosphorus resources contained in curly-leaf pondweed. Consequently, estimates of phosphorus and nitrogen resources contained in milfoil, and those species comprising the mixed community, have been based on results obtained by the Ministry of the Environment in 1984 from studies of macrophytes in Rice Lake. Potassium content was not determined in the 1984 study, necessitating use of potassium results obtained in 1986 to develop estimates of total potassium resources contained in milfoil and the mixed community. Confident estimates of potassium content of curly-leaf pondweed were obtained in 1987 and were used to develop total estimates of potassium resources contained in curly-leaf pondweed.

The calculation of phosphorus contained within curly-leaf pondweed was completed as follows, and serves as an example calculation for determining tissue bound nutrients.

Preliminary Information

Average, wet mass of P. crispus = 1.64 kg/m^2 (Table 1)
Total areal coverage of P. crispus = 5,558 hectares (Section 3.1.1)
Dry Mass/ Wet Mass Ratio = 0.09 (Table 1)
Loss on Ignition (LOI) = 68.83% (Table 1)
Average P (as % of AFDM) = 0.211% (Table 1)

Calculations

Total, wet mass = Total area of growth (ha) x Average Wet Mass (kg/m^2) x 10,000 m^2/ha

Total, wet mass = 5,558 ha x 1.64 kg/m^2 x 10,000 m^2/ha
= 91,150,000 kg
= 91,150 tonnes

Total, Dry Mass = Total, wet mass (t)
x Dry Mass/ Wet mass Ratio

Total, Dry Mass = 91,150t x .09
= 8,204 tonnes

Total, ash free dry mass = Total, dry mass (t) x LOI

Total, ash free dry mass = (8,204t x 68.83)/100
≐ 6,720 tonnes

Total, tissue bound phosporus = (AFDM (t) x P(%))/100

Total, tissue bound phosporus = (6,720t x 0.211)/100
= 11.9 tonnes

Table 7 indicates the total, wet mass of the various macrophyte species and communities, the total dry mass, the total ash free dry mass, and total tonnes of phosphorus, nitrogen and potassium contained within lake macrophytes, for the May - June 1987, June - July and September 1986 survey periods. Using the 1987 curly-leaf pondweed tissue nutrient values in addition to 1984 milfoil tissue nutrient values a total of 16.2 tonnes, 148.3 tonnes and 153.8 tonnes of phosphorus, nitrogen, and potassium respectively, are contained within macrophyte tissues in early summer. By September, 5.1 tonnes, 33.7 tonnes, and 6.5 tonnes of phosphorus, nitrogen, and potassium respectively, are retained within the macrophyte biomass.

A net shift of 11.1 tonnes of phosphorus from macrophytes to other components of the aquatic environment occurs between early July and September. Nutrients contained in curly-leaf pondweed comprise the majority of nutrients released during this period. Likewise, a net release of 114.4 tonnes of nitrogen and 147.5 tonnes of potassium between July and September is largely attributable to curly-leaf pondweed dieback. The ratio of released nitrogen to released phosphorus is approximately 10:1.

Table 7. Total Wet Mass, Dry Mass and Contained Nutrients for Major Macrophyte Species and Plant Communities in Rice Lake

Species or Community	Total Wet Mass (tonnes)	Total Dry Mass (tonnes)	Total AFDM (tonnes)	Total P (tonnes)	Total N (tonnes)	Total K (tonnes)	N:P
Spring - Early Summer							
Curly-leaved Pondweed	91,150	8,200	5,646	11.9	119	150.0	10.0
Milfoil	11,200	1,340	1,001	4.3	29.3	3.8	6.7
Totals	102,350	9,540	6,647	16.2	148.3	153.8	
Early Fall							
Milfoil	8,100	972	726	3.2	21.3	2.8	6.6
Mixed Community	4,550	500	351	1.9	12.4	3.7	6.5
Totals	12,650	1,472	1,077	5.1	33.7	6.5	

The 1987 estimate of curly-leaf pondweed coverage was greater than the 1986 estimate. Due to the lateness of the 1986 survey, areas occupied by curly-leaf pondweed in the spring were covered with milfoil by early summer and as a result total curly-leaf pondweed coverage was underestimated. As well, curly-leaf pondweed was found to grow with uniform coverage to a depth of 1 m, as opposed to 2 m (Limnos, 1987) before merging with the mixed community. The 1987 survey determined an additional 15% coverage of curly-leaf pondweed or 1,358 ha, which correspondingly increased the estimate of total biomass of curly-leaf pondweed.

The total amount of phosphorus and potassium released from curly-leaf pondweed dieback is estimated to be 11.9 tonnes and 150 tonnes, respectively (Table 7). Based on these estimates, the concentration of phosphorus in the water column would be expected to increase by 0.048 mg/L, and potassium by 0.60 mg/L, assuming there was no immediate chemical change or biological uptake of nutrients. Likewise, 119 tonnes of nitrogen is estimated to be contained in the curly-leaf pondweed crop, and given the above assumptions, would increase the concentration of nitrogen in the water column by 0.476 mg/L upon release.

The demand for soluble reactive phosphorus in the aquatic environment is high, and much of the phosphorus released by decaying vegetation is quickly utilized by other aquatic biota. In comparison, however, there is relatively little demand for potassium, and potassium might therefore serve as a conservative indicator of phosphorus release. By knowing the relative amounts of phosphorus and nitrogen contained within the macrophyte tissues, an increase of potassium concentration in the water column should predict the amount of phosphorus being released into the aquatic environment.

During the period of curly-leaf pondweed dieback in 1987, the MOE conducted an intensive water chemistry survey of Rice Lake (MOE, 1987). Between June 8 and June 18, 1987 potassium concentration in the water column rose 0.226 mg/L, coincident with the decline of curly-leaf pondweed. The observed increase of potassium in the water column is approximately 35% of the predicted concentration of potassium release upon dieback of curly-leaf pondweed. A significant amount of nutrients may be be reabsorbed by sediments as the majority of curly-leaf pondweed was observed to slump to the sediment surface during senescence. An increase of total phosphorus in the water column during the same period was not detected and therefore its fate appears to lie elsewhere, possibly in the sediments.

A preliminary estimate of contained nutrient resources developed prior to the 1986 field season estimated that 2.8 tonnes of phosphorus and 17.2 tonnes of potassium were contained in the curly-leaf pondweed crop (Limnos, 1987). The potassium concentration in the water column was projected to increase 0.07 mg/L, as a result of an addition of 17.2 tonnes of potassium, and the phosphorus concentration in the water column to increase by 0.011 mg/L as a result of an addition of 2.8 tonnes of phosphorus. Based on the results of 1987 field work, concentration of phosphorus in the water column would be expected to increase by 0.048 mg/L and potassium concentration would be expected to increase by 0.60 mg/L. The difference is a result of a larger mass of total phosphorus and potassium found in the lake in 1987, in comparison with the preliminary estimates.

Table 8 shows the nutrient content of curly-leaf pondweed and milfoil from samples collected from Rice Lake in 1972, 1984 and 1987.

The 1972 data was expressed as a percentage of the dry mass, and therefore, for comparative purposes, the values are expressed as a percentage of ash free dry mass. The calculation was based on the assumption that the ash content of the 1972 samples was the same as the measured ash contents of samples collected in 1987. The nutrient content of curly-leaf pondweed and milfoil samples collected from Cook's Bay in Lake Simcoe, Ontario, are also included as representative data indicating the nutrient content of the same species taken from a mesotrophic water body (Limnos Limited, 1985).

Table 8. Nutrient content of curly-leaf pondweed and milfoil expressed as a percentage of ash free dry mass.

Year	Lake	Species	%P	%N	N:P
1987	Rice Lake	curly-leaf pondweed	0.21	2.11	10
1984	Rice Lake	curly-leaf pondweed	0.33	2.9	8.7
		milfoil	0.43	2.9	6.7
1972	Rice Lake	curly-leaf pondweed	0.63	3.41	5.3
		milfoil	0.62	3.17	5.1
1985	Cook's Bay	curly-leaf pondweed	0.30	2.47	8.23
		milfoil	0.35	2.85	8.14

Between 1972 and 1987, there has been an apparent decrease in nitrogen and phosphorus content in curly-leaf pondweed, for samples collected in Rice Lake. The N:P ratio increased from 5.3:1 to 10:1 for curly-leaf pondweed (Table 8) as phosphorus content decreased more than nitrogen. The decrease in phosporus may provide an indication of slight change in the eutrophic status of the lake. Reduction of phosphorus input from sewage treatment plants may account for the decrease in phosphorus concentration entering the lake.

Previous macrophyte studies from Rice Lake have recorded biomass values for a number of macrophyte species (MOE, 1976). The highest wet mass values were obtained from the mouths of the Otonabee and Indian Rivers and in the vicinity of White Island, where water clarity was very good. The average values were 1,791, 1,804 and 2,204 g/m^2 respectively. The highest wet mass values from this study also came from the mouth of the Indian River (3,712 g/m^2) and from the south end of White Island (3,024 g/m^2). The vegetation at these locations was mainly muskgrass, Canada waterweed, tapegrass and water stargrass.

In Rice Lake, growth of tape grass and milfoil was recorded to form "dense impenetrable beds" with the wet mass exceeding 1,000 g/m^2 (MOE, 1976). In 1986, the biomass of milfoil was observed to be relatively smaller. The average wet mass of spring milfoil growth in 1986 was about 800 g/m^2, and by fall, 600 g/m^2 (Table 1). These values of milfoil biomass may be less than estimates from other Kawartha Lakes. Painter (1986) indicated that milfoil biomass in Buckhorn Lake was significantly greater than observed in 1986 for Rice Lake. It is possible that the use of a salad spinner in 1986 to remove surficial water before weighing plant samples may have resulted in conservative estimates of biomass relative to previous studies (Section 5.2).

Milfoil growth in the Kawartha Lakes has been significantly reduced in the last few years (Painter, 1986). Grazing by a caterpillar moth larvae (Acentria nivea), has been identified as being the probable cause for milfoil decline in Buckhorn Lake (Painter, 1986). The moth is known to occur in Rice Lake, and could explain the relatively low milfoil biomass recorded in 1986.

Results of a 1987 sub-study on the presence of A. nivea in Rice Lake indicated that 85% of milfoil plants examined were damaged by the larvae (Table 9). Minimal damage to other macrophyte species was observed, however, this damage could not be positively attributed to A. nivea as no larvae were recovered from any species other than milfoil (Table 10). No damage to curly-leaf pondweed was observed. The decline and possible loss of milfoil due to moth infestation, in conjunction with the seasonal decline of curly-leaf pondweed, would create a significant loss of fish habitat by mid-summer in Rice Lake.

The absence of milfoil in MacGregor Bay and an unnamed bay north of Harris Island (Figures 2 and 5) may be a result of moth infestation. In 1985, macrophyte growth was extremely heavy in these waters according to fishermen and resort operators (Section 3.1.2). The water in both bays was turbid with suspended particles, and a number of dredge samples and anchor drags produced no evidence of plant growth in MacGregor Bay in the fall of 1986. A return visit to McGregor Bay in the spring of 1987 found similar turbid water conditions and minimal growth of macrophytes (milfoil, Canada waterweed, curly-leaf pondweed).

5.2 A DISCUSSION OF THE WETLANDS OF RICE LAKE

The dominant wetland habitat found in Rice Lake is the cattail marsh. The marsh community can be found alongside the rivers, creeks and streams that enter the lake, the border of embayments and in undisturbed places along the shoreline where water depth and sediments are suitable for marshes to develop. The largest marsh areas are found at the mouth of the Otonabee and Indian Rivers and on the north shore of the lake just west of Serpent Mounds from Harris Island to Herkimer Point. Less extensive marsh areas are found northwest of Bewdley around Harmony Island, just east of Bewdley, at Goose Creek, Idylwilde Point. and Stoney Creek, the embayment south of White Island and west of Birdsall Point. The marshes occupy approximately 600 ha or 6% of the lake area.

The marshes are mostly homogeneous in species composition and structure. The cattails Typha latifolia and Typha angustifolia dominate the marsh and are found throughout. Swamp loosestrife (Decadon verticillatus), purple loosestsrife (Lythrum salicaria), red-osier dogwood (Cornus stolonifera) and sweet gale (Myrica gale) are found in abundance at the edge of the cattail mat but disappear about 3m into the mat. Less abundant species found at the mat edge include the cyperus-like sedge (Carex pseudo-cyperus), marsh fern (Dryopteris thelypteris), blue joint (Calamagrostis canadensis), jewelweed (Impatiens biflora) and the hoary willow (Salix candida). These species are also found farther into the marsh, but remain small in abundance.

The marsh surface is hummocky with small depressions. Some depressions have standing water which can be 5 cm deep while others are wet to moist with no standing water. This was observed in the marsh areas examined and appeared to be the same for the areas that were observed from the boat.

The exception to the homogeneous cattail marsh can be found at the mouth of the Indian River. This marsh area had a larger woody component in comparison with other marsh areas. The woody species include sweet gale, hoary willow, red-osier dogwood and speckled alder (*Alnus incana* ssp. *rugosa*). The two species of cattail were present although they occupied a smaller percentage of cover in comparison to the other marshes around the lake.

The marsh also supports a number of floating, emergent and submerged macrophytes that are found near the marsh edge and in the channels and openings through the marsh. These include bulrush (*Scirpus validus*), redhead grass (*Potamogeton richardsonii*), lesser duckweed (*Lemna minor*), coontail (*Ceratophyllum demersum*) and white waterlilly (*Nymphaea odorata*).

The Ontario Ministry of Natural Resources surveyed a number of marshes in Rice Lake following the guidelines of "An Evaluation System for Wetlands of Ontario". The evaluation is based on giving value points to a wide range of parameters, some of which are not relevant to this study. As well, the scope of the point value system does not allow for the detail required for a biophysical, ecological study. Some of the plant species inventoried by the survey, not included in the Rice Lake study collection are buttonbush (*Cephalanthus occidentalis*), tamarack (*Larix laricina*), black ash (*Fraxinus nigra*) and American elm (*Ulmus americana*). These species were found in the lowland forests at the back of the marsh areas.

Marshes are known to be highly productive (Whittaker, 1975) and are thought to enhance water quality (Kvet, 1975). They provide habitat for a diversity of wildlife species and trap and stabilize sediments that run off from surrounding land (Sparling, 1979). Their affect on water temperature, nutrient cycling, water retention and circulation in Rice Lake is not well documented.

The marshes of Rice Lake do not appear to be changing in terms of areal coverage. Field work conducted in 1986 revealed that marsh perimeters are very similar to perimeters indicated on navigational charts produced by the Canadian Hydrographic Service. This is probably a function of the lake water levels remaining constant from 1968 to 1986.

6. ADDITIONAL STUDIES

6.1 THE PRESENCE OF ACENTRIA NIVEA ON EURASIAN WATERMILFOIL IN RICE LAKE.

During June and July, 1987, a small study was conducted to investigate the presence and abundance of the moth caterpillar, *Acentria nivea*, in Rice Lake. The larval stage of the species feeds on the apical tips of milfoil, and uses the stem and leaves for shelters. The species has been documented in other Kawartha Lakes and is felt to be responsible for the decline of milfoil in Lake Scugog and Buckhorn Lakes in 1986 (Painter and McCabe, 1987). Milfoil is the predominant macrophyte in Rice Lake following the seasonal dieback of curly-leaf pondweed, and loss of milfoil cover as a result of damage by *A. nivea* would seriously impact the total macrophyte community.

In order to investigate abundance of *A. nivea* 20 samples of milfoil were collected by divers from five different locations supporting milfoil growth. The top 25 cm of the apical tip of the plants were retained as samples and examined for presence of the larvae. Samples of other common macrophyte species found in the lake were collected from two locations and examined for larvae or grazing.

Table 9 indicates the number of larvae and damaged stem samples, as well as undamaged stem samples, recovered from five sampling sites. Larvae or grazing damage was observed on at least half of all samples collected from four of the five sites. Larvae or damage was observed on 80% or more of samples collected at White Island, Sheep Island and Sager Point. Larvae or damage was observed on 70% and 45% of samples collected from the bay east of the mouth of the Otonabee River, and the

Table 9. *Acentria nivea* on Eurasian Watermilfoil in Rice Lake, Ontario, 1987

Date	Station	Plant Condition
June 2	White Island	4 healthy 16 grazed 11 larvae
June 2	Sager Point	3 healthy 17 grazed 15 larvae
June 2	Sheep Island	4 healthy 16 grazed 8 larvae
June 18	Bay East of Close Point	11 healthy 8 grazed 3 shelters
June 18	Bay East of Otonabee River Mouth	6 healthy 11 grazed 3 larvae 6 shelters

- 20 samples of apical tips of milfoil were examined for each station

Table 10. Acentria nivea on Some Common Submerged Macrophytes in Rice Lake, Ontario, 1987

Species	Plant Condition Site A	 Site B
Ceratophyllum demersum	healthy	2 grazed
Elodea canadensis	14 healthy 6 grazed	healthy
Heteranthera dubia	8 bore holes	healthy
Potamogeton crispus	healthy	healthy
Vallisneria americana	2 bore holes at leaf base	healthy

- Site A is the Bay East of Close Point
  Site B is the Bay East of the mouth of the Otonabee River

- 20 specimens of each species were examined except for C. demersum from Close Point (12) and C. demersum (10) and P. crispus (5) from the Otonabee River Mouth.

bay east of Close Point, respectively. The lower frequency of the latter two sites may have been due to later sampling in mid-July when water temperature is high enough to promote the pupation from larvae to adult (Painter, 1987).

Damage to the plants included stem and leaf grazing, bore holes and shelters formed from leaves. Larvae were either observed boring in the stem, encased in leaf shelters, or grazing on the leaves. Up to three larvae were collected from single stems, though larvae were recovered from less than half of the damaged stems. Painter and McCabe (1987) commonly found milfoil plants from Rice Lake with apical tips missing. This form of damage was not observed for plant samples collected during 1987, though severe stem boring was observed to severly weaken the stem which could result in detachment of the apical tip.

Other macrophytes examined were curly-leaf pondweed, tapegrass, Canada waterweed, coontail and water stargrass. The results are presented in Table 10. A small number of collected coontail samples had grazing damage, though no larvae were recovered. Some damage to Canada waterweed and tapegrass was observed, though the damage could not be conclusively attributed to A. nivea. No damage to curly-leaf pondweed was observed.

The macrophyte bed in the vicinity of the limnocorrals located on the east side of Sheep Island was dominated by curly-leaf pondweed with small isolated clumps of milfoil. Seventy-five percent of milfoil tips were observed to have been damaged by A. nivea. Larvae and shelters were observed on 50% of the plants. With the abundance of A. nivea in this area of dense pondweed growth it would be anticipated that if curly-leaf pondweed were suitable for grazing there should have been more evidence than what was observed.

Observations on the morphology of different macrophytes, including curly-leaf pondweed, may indicate the preference of A. nivea for milfoil. Milfoil stem tissue is soft with a large lacunae system that makes it vulnerable to boring. The fine leaves are suitable for grazing and offers sites for shelter cases. The other macrophytes examined have stems which are usually smaller in diameter, and upon observation, appear to have a smaller lacunae system. Curly-leaf pondweed has a small diameter stem which would prohibit larvae from boring and the large surface area of the leaves do not provide suitable shelter habitat. The macrophyte most similar to milfoil in morphology is coontail, of which a small number of examined samples had recognizable grazing damage.

6.2 AN INVESTIGATION INTO RELATIONSHIPS OF WET VOLUME, WET MASS, AND DRY MASS WITH ASH FREE DRY MASS FOR VARIOUS AQUATIC PLANT SPECIES.

Intoduction and Objectives

Determining the amount of nutrients contained in the tissues of macrophytes is central to understanding the role macrophytes play in nutrient recycling and their potential to affect water quality. In order to estimate the nutrient resources contained within the macrophyte community of a lake, an estimate of total biomass is required. In a large lake, many biomass samples may be required to estimate total biomass with confidence.

Present techniques for analyzing biomass samples are time consuming and prone to error. Current practice requires oven drying of the total sample at 60^{0}C followed by a laboratory ashing procedure to determine a percent organic content. The effort required to process samples is substantial, and can limit the number of samples that are collected. At present, there is no standard procedure for removing excess surficial water from plant samples, resulting in varying amounts of water being included in wet biomass measurements. As well, variable amounts (20% - 80%) of inorganic deposits can accumulate on the plant exterior, and these deposits can affect the accuracy of measured wet mass and dry mass. For this reason, the reporting of ash free dry mass (AFDM) is preferable to dry mass.

The purpose of this study was to determine whether acceptable correlations could be developed between ash free dry mass and wet mass, ash free dry mass and wet volume, and ash free dry mass and dry mass.

The correlations were determined statistically using linear regression. If acceptable correlations were developed, any one of the three parameters (wet volume, wet mass, and dry mass) could be used directly to predict the AFDM of collected samples. Accurate measurements of plant volume can easily be taken in the field, and the use of either wet volume or wet mass to determine AFDM would reduce the amount of laboratory analysis required for drying and ashing collected samples. It is anticipated that the procedure would increase the number of biomass samples that can be practically collected.

Two new techniques that could improve the accuracy of biomass measurements were used in this study. Normally, fresh plant samples are weighed to determine the wet mass. However, measuring biomass by volume minimizes the affect of surface deposits on the biomass measurement, as the deposits are typically carbonates and have small volumes relative to their mass. In addition, to improve the accuracy of both wet volume and wet mass measurements, freshly collected plant samples were initially spun in a hand operated salad spinner to remove the majority of surficial water centrifugally. Acceptable correlations between volume and ash free dry mass, based on a limited number of samples, have previously been used to estimate nutrients contained within macrophytes (Limnos, 1985).

Methods

In order to evaluate the relationships of volume, wet mass, and dry mass with AFDM, sixty eight plant samples were collected during late June and July, 1986. The samples were collected randomly from macrophyte beds from different areas of the lake. In total, twenty samples of tapegrass, twenty three samples of milfoil, and twenty samples of water stargrass were collected. Only five samples of curly-leaf pondweed were collected, however, as most growth of curly-leaf pondweed had disappeared from Rice Lake by late June.

The use of a salad spinner to remove surficial water from collected plant samples was central to the study methodology. To initially determine the effectiveness of the salad spinner, different plant samples were spun varying numbers of revolutions. As well, the effect of respinning plant samples was investigated. It was determined that twenty fast revolutions was usually sufficient to remove the bulk of the surfical water. The amount of water removed during the initial spinning of the plant sample was usually substantial, and respinning a plant sample removed little additional water. Larger plant samples were sometimes respun to remove as much water as possible, and very large samples were subdivided and spun individually. Spun plant samples were easily handled, and felt relatively dry to the touch.

Any roots, or plants of other species, were removed from the sample immediately following collection. Approximately half of the samples of each species were treated with a 2%, HCl acid bath to remove carbonate deposits on the plant exterior. This was done such that carbonate deposits would not be included as part of the inorganic fraction of the plant, resulting in a lower organic content upon LOI analysis. The wet mass of the sample was determined following removal of surficial water using the salad spinner. The wet volume was then measured by water displacement, using a 4000 ml graduated cylinder. The plant samples were subsequently air dried, and the dry mass of the samples determined.

The dried plant samples were submitted to the Trent Aquatic Research Center laboratories at Trent University, Peterborough, Ontario, for determination of organic content by measuring loss on ignition (LOI). The dry mass of each sample was multiplied by its respective LOI, and the ash free dry mass determined. The data acquired was statistically tested using linear regression to determine the relationship between wet volume and AFDM, wet mass and AFDM, and dry mass and AFDM. Appendicies F, K, L, and M present the sampling date, sampling location, treatments and measured biomass parameters for each biomass sample.

Results

The results of the regression analysis are presented in Table 11. As indicated in Table 11, good correlations ($r^2 > 0.8$) are obtained between dry mass and ash free dry mass for most of the data sets. There is little difference between the regression coefficients for wet volume - AFDM and wet mass - AFDM correlations. Wet volume and wet mass produce acceptable correlations when plant species are treated separately, except in the case of water stargrass, where suitable correlations were obtained using dry mass only. Treating samples with an acid bath did not significantly improve the correlations.

Lumping of all data produced poor correlations when wet volume and wet mass were used. Figures 9, 10 and 11 plot regressions of the wet volume, wet mass and dry mass vrs. ash free dry mass for curly-leaf pondweed respectively. Figures 12, 13 and 14 plot the regressions for wet volume, wet mass and dry mass vs. ash free dry mass for milfoil samples that did not receive an acid bath.

Table 11. Results of Regression Analysis for Wet Volume, Wet Mass, and Dry Mass vs. AFDM.

Species	Treatment	Vol. vs. AFDM (r^2)	Wet Mass vs. AFDM (r^2)	Dry Mass vs. AFDM (r^2)	Sample Size
All Data		.656	.638	.913	68
All Species	No Acid Bath	.595	.564	.849	35
Curly-leaf Pondweed	Lumped Data	.963	.990	.999	5
Tapegrass	Lumped Data	.860	.872	.670	20
	Acid Bath	.678	.749	.918	10
	No Acid Bath	.942	.915	.868	10
Milfoil	Lumped Data	.939	.919	.913	23
	Acid Bath	.955	.941	.988	12
	No Acid Bath	.945	.922	.826	11
Water Stargrass	Lumped Data	.673	.636	.915	20
	Acid Bath	.681	.698	.993	9
	No Acid Bath	.377	.362	.924	11

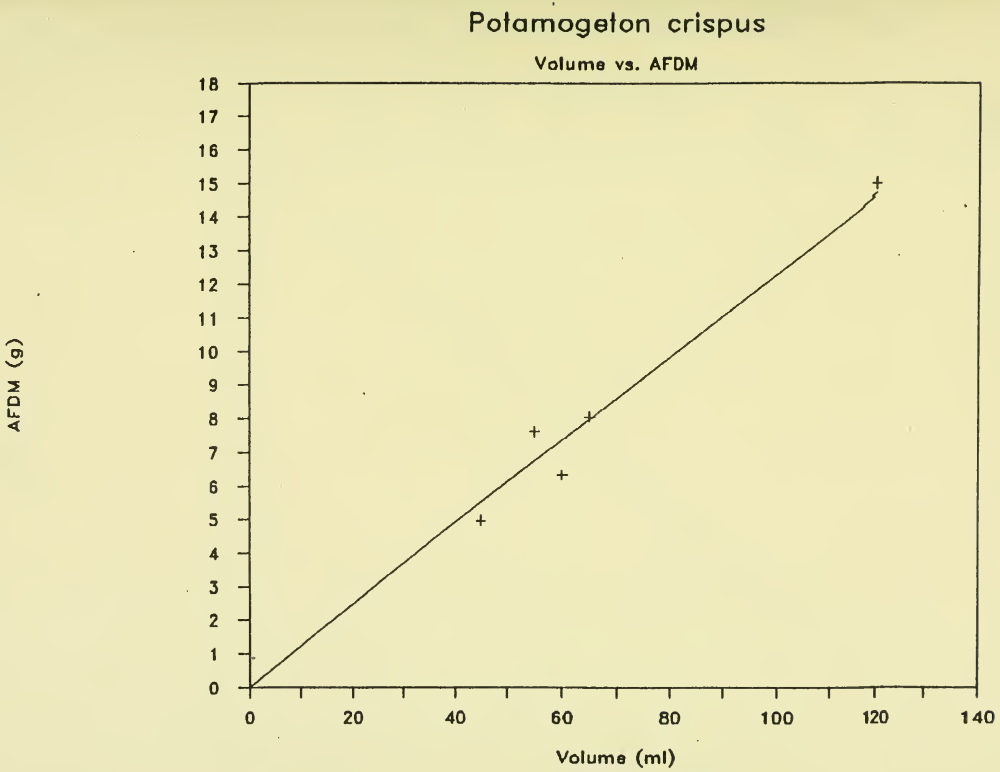


Figure 9. Relationship between Wet Volume and Ash Free Dry Mass for Potamogeton crispus. ($r^2 = 0.963$)

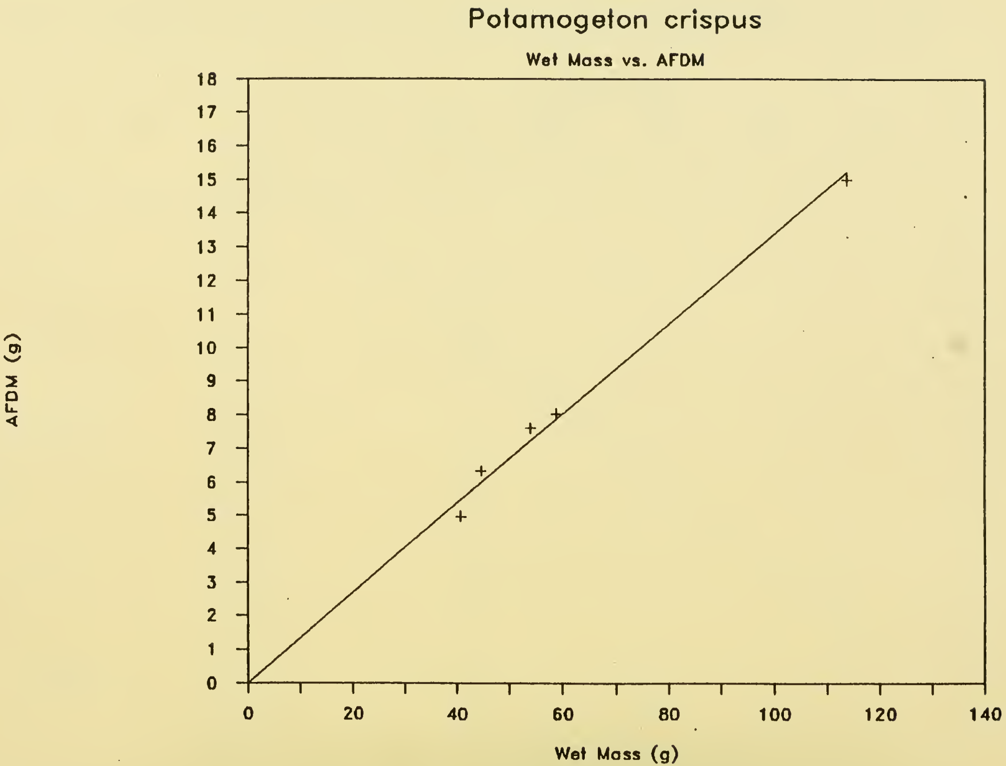


Figure 10. Relationship between Wet Mass and Ash Free Dry Mass for Potamogeton crispus (r^2 = 0.990))

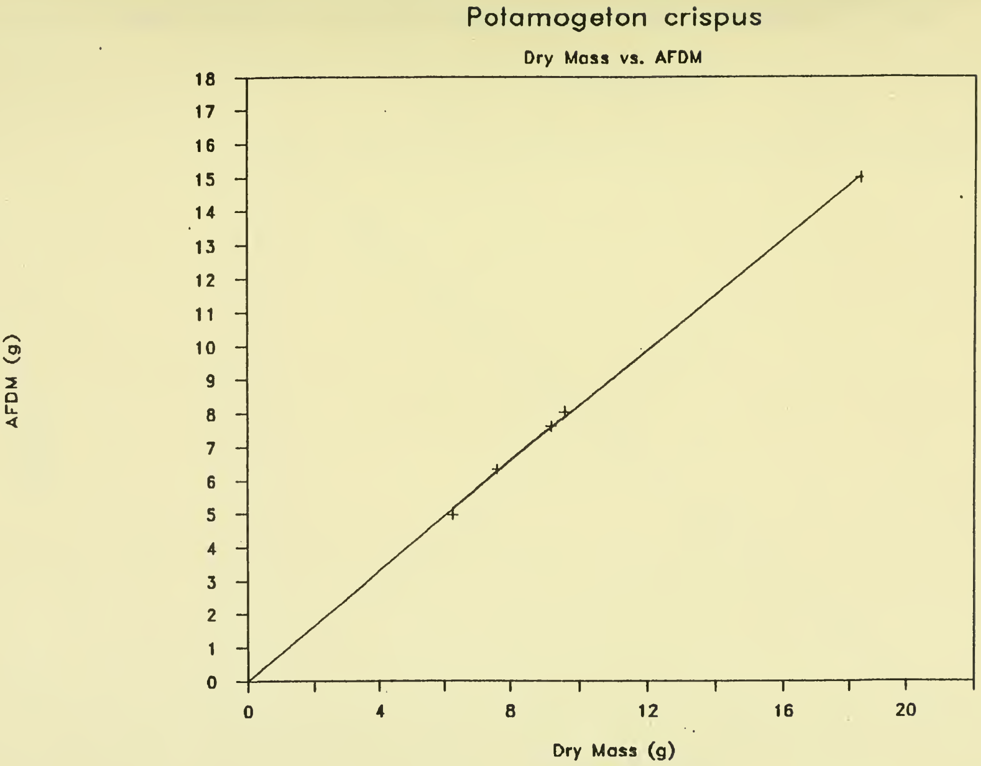


Figure 11. Relationship between Dry Mass and Ash Free Dry Mass for Potamogeton crispus. (r^2 = 0.999)

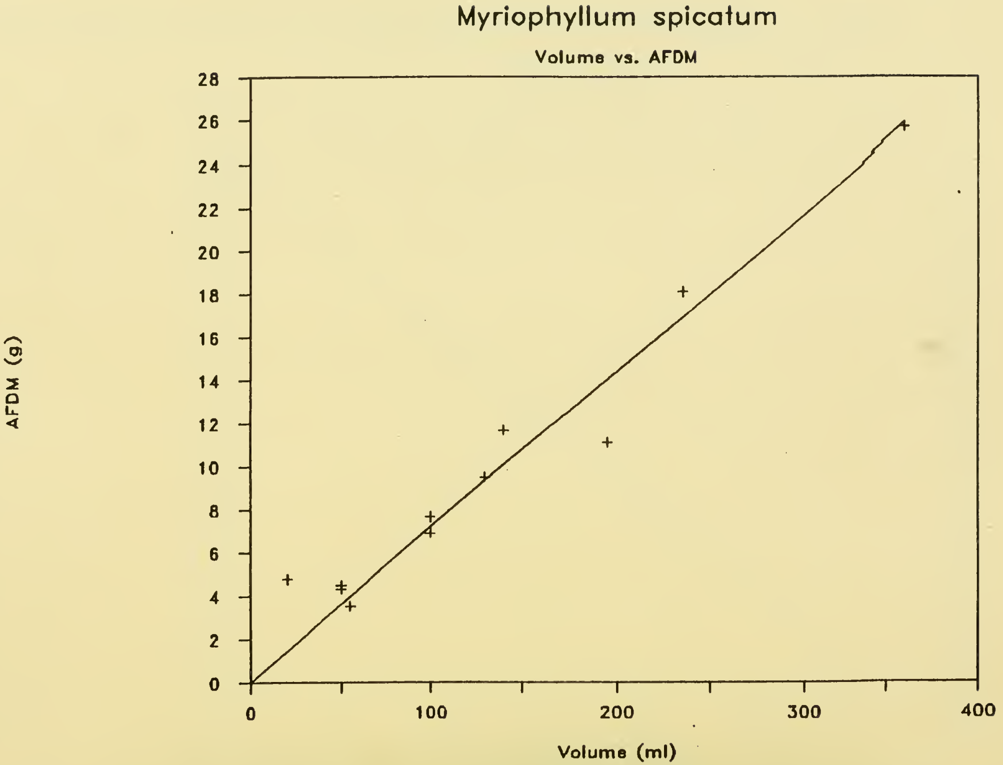


Figure 12. Relationship between Volume and Ash Free Dry Mass for Myriophyllum spicatum. ($r^2 = 0.945$)

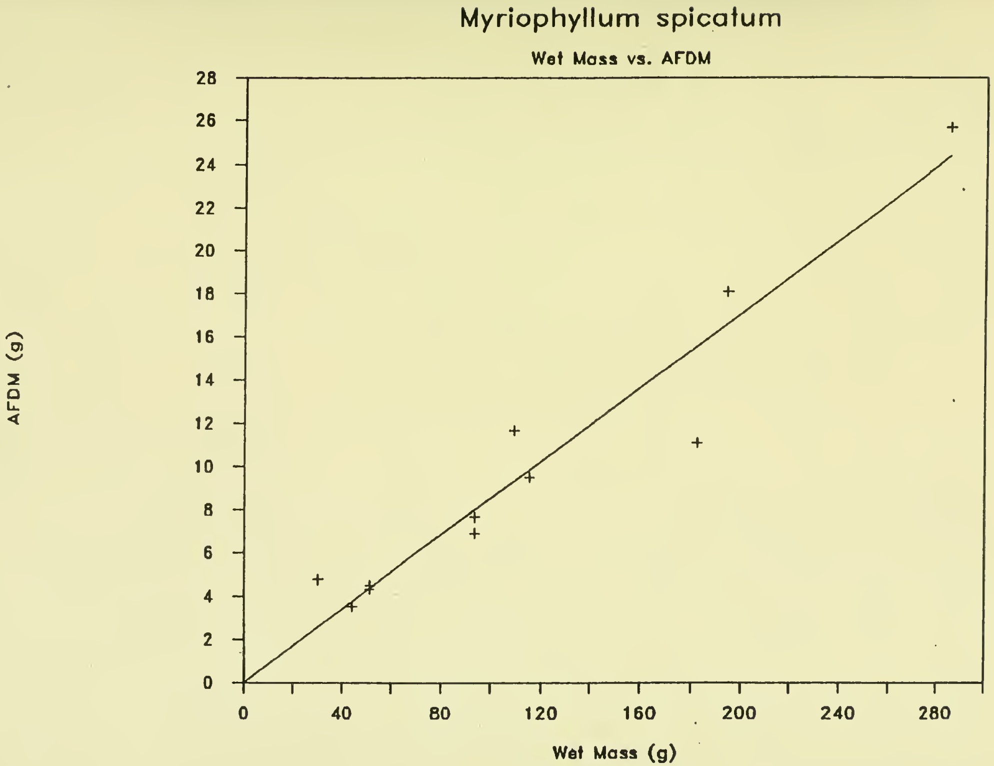


Figure 13. Relationship between Wet Mass and Ash Free Dry Mass for *Myriophyllum spicatum*. ($r^2 = 0.922$)

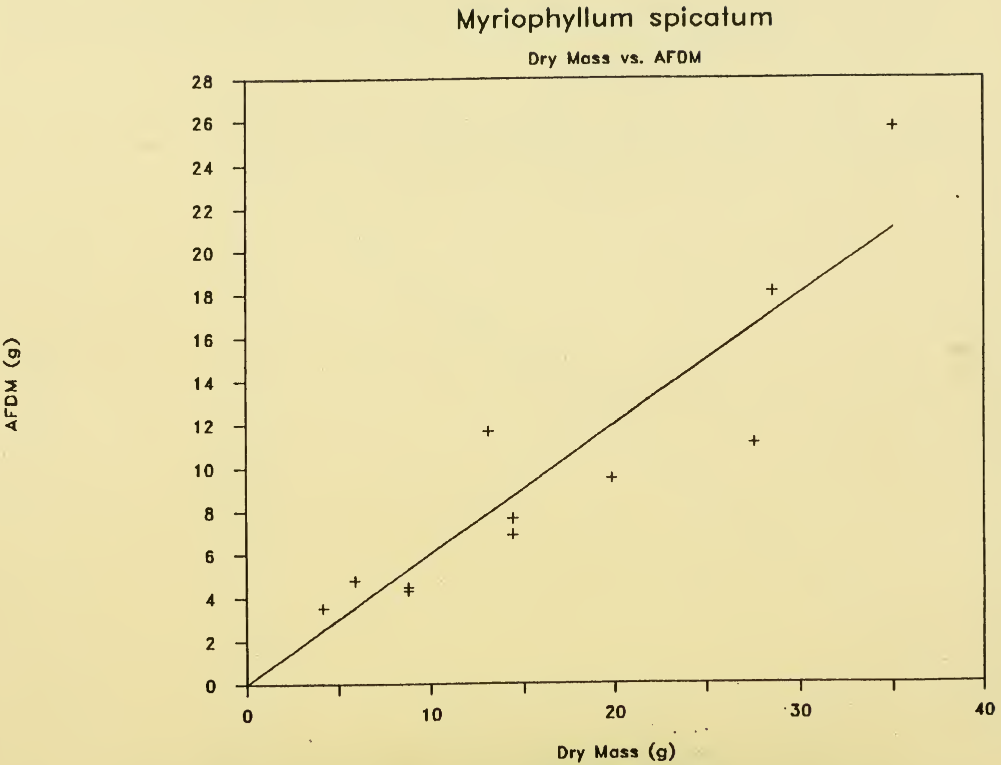


Figure 14. Relationship between Dry Mass and Ash Free Dry Mass for Myriophyllum spicatum. (r^2 = 0.826)

Discussion

The wet volume or wet mass were equally acceptable as a means to predict AFDM, when species were treated independently. The addition of an acid bath treatment slightly improved the correlations for milfoil. While the correlations between dry mass and wet mass were good in all cases, the use of dry mass to predict ash free dry mass has practical limitations. If laboratory facilities are required to dry samples, then excessive costs would be anticipated. The time required for delivery and processing samples may be substantial. Even if air drying is used, considerable effort is expended in storing and handling a large number of samples. Suitable facilities to dry samples may also be lacking.

Several conclusions can be drawn from this study. It would appear important that any relationships developed to predict ash free dry mass from wet mass or wet volume be specific to a single species. However, some species, such as water stargrass, may not provide acceptable correlations other than between wet mass and ash free dry mass. Each species should be assessed individually to determine if predictive relationships can be developed.

If the use of wet volume or wet mass correlations is desired, it may be important to apply any developed relationships for only a limited portion of the growing season. This may be especially true for species such as milfoil that remain in the water column for long periods of time, and have the opportunity to continuously accumulate deposits on the plant surface. This complication might be largely avoided if an acid bath was used at all times and confidence developed in the efficiency of the acid bath to remove surface deposits. Milfoil plants treated with an acid bath had an organic content of 75.14% while milfoil plants not having an acid bath recorded an organic content of 66.15% (Appendix K). Neither the efficiency of the acid bath, nor its affect on the subsequent determination of nutrient content, were investigated in this study.

7. REFERENCES

1. Auer, N.A. (Ed.) 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. The Great Lakes Fishery Commission. Ann Arbor, Mich. Special Publication 82-3.

2. Britton, N.L., and H.A. Brown. 1970. An Illustrated Flora of the Northern United States and Canada. 2nd Ed. Dover Publications, Inc., New York.

3. Bulkley, R.V., V.L. Spykerman, and L.E. Inmon. 1976. Food for the pelagic young of walleyes and five cohabiting fish species in Clear Lake, Iowa. Trans. Amer. Fish. Soc. 104: 726-730.

4. Engel, S. 1985. Aquatic community interactions of submerged macrophytes. Department of Natural Resources. Technical Bulletin No. 156. Madison, Wisconsin.

5. Faber, D.J. 1981. A light trap to sample littoral and limnetic regions of lakes. Verh. Internat. Verein. Limnol. 21: 776-781.

6. Gerloff, G.C. and P.H. Krombholz. 1966. Tissue analysis as a measure of nutrient availability for the growth of angiosperm aquatic plants. Limnol. Oceanogr. 11: 529-537.

7. Gregory, R.S, and P.M. Powles. 1985. Chronology, distribution and sizes of larval fish samples by light traps in macrophytic Lake Chemung. Can. J. Zool. 63: 2569-2577.

8. Hanna, J.E. and Associates Inc. 1984. A management strategy for the restoration of aquatic vegetation in Rondeau Bay, Lake Erie.

9. Hurley, D.A., W.J. Christie, C.K. Minns, E.S. Millard, J.M. Cooley, M.G. Johnson, K.H. Nicholls, G.W. Robinson, G.E. Owen, P.G. Sly, W.T. Geiling, and A.A. Crowder. 1986. Trophic structure and interactions in the Bay of Quinte, Lake Ontario, before and after point-source phosphorous control. P. 259-270. In C.K. Minns, D.A. Hurley, and K.H. Nicholls (ed.) Project Quinte: point-source phosphorous control and ecosystem response in the Bay of Quinte, Lake Ontario. Can. Spec. Publ. Fish Aquat. Sci. 86: 270 p.

10. Hutchinson, G.E. 1975. A Treatise on Limnology. Vol 3. Limnological Botany. John Wiley and Sons. New York. 660p.

11. Jones, R.C., Walti, K. and M.S. Adams. 1983. Phytoplankton as a factor in the decline of the submersed macrophyte Myriophyllum spicatum L. in Lake Wingra, Wisconsin, U.S.A. Hydrobiol. 107: 213-219.

12. Kvet, J. 1975. Growth and mineral nutrients in shoots of Typha latifolia L. Symp. Biol. Hung. pp. 113-123.

13. Limnos Limited, 1987. Rice Lake Study. Macrophyte distribution, composition, and biomass characteristics in "Rice Lake Study, Interim Status Report".

14. Limnos Limited, 1985. Aquatic plant assessment, Cook's Bay, Lake Simcoe. Distribution, biomass, tissue nutrients and species composition.

15. McAndrews, J.H. 1984. Late quaternary vegetation history of Rice Lake, Ontario, and the McIntrye Archaeological Site. National Museum of Man, Mercury Series, Archaeological Survey of Canada. Paper No. 126.

16. Miraldo, D. 1986. Pers. comm. Joint meeting with Rice Lake Study consultant group and Ontario Ministry of the Environment and Ontario Ministry of Natural Resources staff.

17. Nicholls, K.H., and D.A. Hurley. 1986. (Draft) Recent changes in the phytoplankton of the Bay of Quinte: the relative importance of fish and phosphorous.

18. Ontario Ministry of Natural Resources (MNR) 1980. B. Potter. Rice Lake littoral zone study. Kawartha Lakes Fisheries Assessment Unit.

19. Ontario Ministry of the Environment (MOE). 1987. B.P Neary. Preliminary results of an intensive water chemistry survey of Rice Lake coincident with the die-off of Potamogeton crispus. Limnology Section, Water Resources Branch, Dorset Research Centre.

20. Ontario Ministry of the Environment and Ontario Ministry of Natural Resources. 1976. I. Wile. The macrophytes of the Kawartha Lakes in "The Kawartha Lakes water management study - water quality assessment (1972-1976)".

21. Painter, D.S. and K.J. McCabe. 1987. Investigation into the disappearance of Eurasian water milfoil in the Kawartha Lakes. National Water Research Institute, Environment Canada, Burlington, Ontario.

22. Painter, S. 1986. Pers. comm.

23. Pennak, R.W. 1953. Fresh-Water Invertebrates of the United States. The Ronald Press Company, New York.

24. Reimer, D.N. 1984. Introduction to Freshwater Vegetation. AVI Publishing Co. Inc., Westport, Conn.

25. Riley, J.L. 1979. Ontario's Pondweeds (Genus Potamogeton). The Ontario Field Biologist. Vol. 33, No. 2.

REFERENCES (cont'd)

26. Rogers, K.H. and C.M. Breen. 1980. Growth and reproduction of Potamogeton crispus in a South African lake. J. Ecol. 68: 561-571.

27. Sastroutomo, S.S. 1981. Turion formation, dormancy and germination of curly pondweed, Potamogeton crispus L. Aquatic Botany 10: 161-173.

28. Sculthorpe, C.D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold Publishers Ltd. London.

29. Sparling, J. 1979. Ontario Naturalist. Vol. 9, No. 2. P. 12-17.

30. Tobiessen, P., and P.D. Snow. 1984. Temperature and light effects on the growth of Potamogeton crispus in Collins Lake, New York State. Can. J. Bot. 62:2822-2826.

31. Whittaker, R.H. 1975. Communities and Ecosystems. 2nd Ed. Macmillan Publishing Co. Inc., New York.

8. APPENDICES

Appendix A: *Potamogeton crispus* Distribution Transects, 1987

Date	Transect	General Location	Depths Covered (m)	Macrophyte Status
May 26	1	Between Gores Landing and Pine Tree Pt. toward Long Island	2.0 to 4.5	continuous P. crispus to 4.0m.
May 26	2	Pine Tree Pt. toward Wallace Pt.	2.0 to 4.5m	continuous P. crispus to 4.0m.
May 26	3	W of Wallace Pt. toward W of Grape Island	3.5 to 4.0m	discontinuous P. crispus.
May 26	4	Otonabee R. East Bay toward River navigation marker	1.25 to 2.0m	discontinuous mixed community*.
May 27	5	Between Hatrick Pt. and Picnic Pt. toward W of Tick Island	3.0 to 4.0m	continuous P. crispus for 0.8km.
May 27	6	Idylwilde Pt. toward Plum Pt.	2.75 to 3.5m	continuous P. crispus to 3.5m.
May 27	7	S Sugar Island toward Rack Island	2.0 to 8.0m	discontinuous to very thin growth. no growth below 3.5m.
May 27	8	E of Robin Landing N to Grasshopper Island	3.0 to 5.5m	no growth.
May 27	9	Birdsall Pt. to N Pt. Margaret Island	1.5 to 4.5m	growth from 1.75 to 2.5m.
June 11	10	E of Bewdley toward Harmony Island	2.0 to 5.0m	continuous P. crispus to 3.75m.
June 11	11	E Ley Pt. toward Wallace Pt.	2.0 to 5.0m	thick continuous P. crispus to 3.5m.
June 11	12	N shore toward Pine Tree Pt.	2.0 to 4.0m	continuous to discontinuous growth.
June 11	13	W of Tick Island to S shore	1.5 to 4.0m	growth from 2.0 to 3.75m (continuous).

* mixed community - Eurasian watermilfoil, coontail, Canada pondweed, *Chara*

Appendix B: Fathometer Transects, June-July, 1986

Date	Transect	General Location	Depths Covered(m)	Macrophyte Status
June 18	B1	Long Island NE to marina	.5 to .5 (2.5)*	Intermittent P. crispus and milfoil
June 18	B2	Wallace Point SE to Long Island	.5 to .5 (5)	P. crispus growth to 3.75m
June 18	B3	Long Island to West Sugar Island	.5 to .5 (4.5)	Continous P. crispus to 3.75m
June 18	B4	Sheep Island N to Jubilee Point	.5 to .5 (3)	Patchy milfoil on 2m humps
June 18	B5	Bouy at Otonabee R. to Spook Isl.	.5 to .5 (3)	Barren of macrophytes
June 18	A1	Long Island W to West Grape Isl.	.5 to .5 (5)	P. crispus to 3.75m
June 19	A2	Pine Tree Pt. N toward Wallace Pt.	.5 to 5 (6)	Barren of macrophytes
June 19	A3	Ley Point towards north	.5 to 3.5 (5)	Some P. crispus near shore
June 19	A4	East of Bewdley to North of Bewdley	.5 to .5 (3)	Mix of milfoil to 2m and P. crispus
June 20	C1	Close Pt. N to Spook Isl.	.5 to .5 (5.5)	Discontinuous P. crispus to 3.75m
June 20	C2	Spook Isl. E to Tick Isl.	.5 to .5 (3.5)	Continuous P. crispus growth
June 20	C3	Tick Isl. NW toward white church	.5 to 4 (4)	Some P. crispus near Tick Isl.
June 23	C4	Picnic Pt. NE to Herkimer Pt.	.5 to .5 (2.5)	Heavy milfoil near Picnic Pt.
June 23	C5	Herkimer Pt. E to Paudaush Pt.	.5 to .5 (3.25)	Thin, discontinuous growth of P. crispus, milfoil
June 23	C6	Paudaush Pt. E to Curtis Pt.	.5 to .5 (4)	Mainly barren, some P. crispus near Paudaush Isl.
June 23	D1	Rainy Pt. to near Sugar Isl.	.5 to 1.5 (2)	Thick and continuous milfoil growth
June 23	D2	Foley Pt. to Grasshopper Isl.	.5 to .5 (6)	Milfoil and P. crispus near Upper Foley Island.
June 23	D3	Robin Landing W to Hickory Island	.5 to .5 (4.5)	Thin P. crispus growth to 3.75m
June 26	C7	Tick Island NE to Idlywilde Pt.	.5 to .5 (3.75)	Thin but continuous P. crispus growth
June 30	E1	Margaret Isl. N to mainland	.5 to .5 (6.5)	Barren of macrophytes
June 30	E2	Birdsalls Pt. S to mainland	.5 to .5 (7)	Barren of macrophytes
June 30	E3	Grasshopper Isl. N toward Elmhirst Inn	.5 to 4.5 (6.5)	Milfoil near Grasshopper Isl., otherwise barren
July 2	B6	Gores Landing to Sheep Island	.5 to .5 (5.5)	Thin P. crispus growth near Gores Landing
July 2	WD1	Near Woodduck Creek	.5 to .5 (2)	Patchy but continuous milfoil

* Initial and final depths of fathometer transect. Bracketed figure is maximum depth recorded during transect.

Appendix B: Fathometer Transects, June-July, 1986 (cont'd)

Date	Transect	General Location	Depths Covered(m)	Macrophyte Status
July 2	WD2	Near Woodduck Creek	.5 to .5 (1.25)	Patchy but continuous milfoil
July 2	WD3	Near Woodduck Creek	.5 to .5 (1)	Some milfoil, chara
July 3	D4	Rack Isl. to White Isl.	.5 to .5 (2)	Very thick and continuous milfoil
July 3	D5	White Isl. SE to mainland	.5 to .5 (3)	Continuous milfoil growth in waters less than 2.3m
July 3	D6	Shearer Pt. N to Sugar Isl.	.5 to .5 (4)	Patchy milfoil near Sugar Island
July 18	B9	West of Jubilee Pt. toward W. Sugar Isl.	.5 to 2.8 (2.8)	Vallisneria and milfoil growth at start of transec
July 18	B7	Near Otonabee R. mouth toward Tick Isl.	.5 to .5 (2.8)	Mixed community initially, Vallisneria to 2m
July 18	B8	Bay east of Close Pt. toward Tick Isl.	.5 to 3.5 (3.5)	Mixed community inshore, milfoil to 2m

* Initial and final depths of fathometer transect. Bracketed figure is maximum depth recorded during transect.

Appendix C: Potamogeton crispus Biomass Sampling Results, 1987

Date	Transect	Sample Code	General Location	Depth (m)	Wet Volume (ml/m^2)	Wet Mass (g/m^2)
June 3	GL	GL-1	Off Gores Landing Public Wharf	2.0	933.2	722.0
"	"	GL-2	"	2.5	1346.8	1037.2
"	"	GL-3a	"	3.0	3193.2	2400.0
"	"	GL-3b	"	3.0	2340.0	1633.2
"	"	GL-4a	Between Gores Landing and Sheep Island	3.5	1873.2	1597.2
"	"	GL-4b	"	3.5	2373.2	2049.2
June 5		SS-1	SW Sheep Island toward Victoria Inn	3.0	n.m.	1825.2
"		SS-2	" Just inside weed line	3.5	n.m.	1258.8
"		SI-1	Adjacent limno-corrals	2.5	n.m.	1128.8
"		SI-2	NE tip of Sheep Island	2.5	n.m.	1456.0
June 11	J-11-1	J-11-1a	S of Harmony Island	2.5	2780.0	n.m.
"	"	J-11-1b	"	3.1	1673.2	n.m.
"	"	J-11-1c	"	2.2	2640.0	n.m.
"	J-11-2	J-11-2a	Off NE Ley Pt.	2.5	2886.8	n.m.
"	"	J-11-2b	"	2.9	3206.8	n.m.
"	"	J-11-3a	"	3.0	716.0	n.m.
"	"	J-11-3b	"	3.0	1353.2	n.m.

Appendix C: *Potamogeton crispus* Biomass Sampling Results, 1987 (cont'd)

June 14	J-14-1	J-14-1b	W of Tick Island	3.0	886.4	n.m.
"	"	J-14-1c	"	3.0	2233.2	n.m.
"	J-14-2	J-14-2a	300m E off Spook Island	3.3	2706.8	n.m.
"	"	J-14-2b	1km E of Spook Island	3.3	1506.4	n.m.

n.m. - not measured.

Appendix D: Biomass Sampling Results June - July, 1986

Date	Transect	Sample Code	General Location	Depth (m)	Loran C Coordinates	Wet Volume (ml/m^2)	Wet Mass (g/m^2)	Dry Mass (g/m^2)	Species Composition
June 30	A5	A51	Near Bewdley	2.0	16,036.9 59,493.3	n.r.*	762.0	88.0	60% M. spicatum 40% P. crispus
June 30	A7	A71	South of Pengally Landing near Bewdley	3.8	n.r.	no plants recovered			
June 30	A7	A72	South of Pengally Landing near Bewdley	3.0	16,027.4 59,498.3	n.r.	158.7	10.0	100% P. crispus
June 30	A7	A73	South of Pengally Landing near Bewdley	3.75	16,030.1 59,496.9	n.r.	2.8	0.9	100% P. crispus
June 25	n.a.*	BS1	Sheep I. Limnocorrals	2.2	16,015.4 59,523.1	n.r.	1,987.0	176.0	100% P. crispus
June 25	n.a.	BS2	Sheep I. Limnocorrals	2.2	16,015.8 59,523.1	n.r.	826.0	76.0	100% P. crispus
June 25	n.a.	BS3	Sheep I. Limnocorrals	2.2	16,016.3 59,523.1	n.r.	1,570.0	141.0	100% P. crispus
July 1	n.a.	BW1	Near Woodduck Crk.	1.2	16,009.4 59,509.6	n.r.	767.0	100.0	100% M. spicatum
July 1	n.a.	BW2	Near Woodduck Crk.	1.2	16,009.5 59,508.6	n.r.	941.3	115.3	100% M. spicatum
July 1	n.a.	BW3	Near Woodduck Crk.	1.2	16,009.6 59,508.6	n.r.	577.0	97.0	100% M. spicatum
June 28	C2	C21	Between Spook and Tick Island	3.5	16,006.2 59,531.8	n.r.	276.0	24.0	100% P. crispus
June 27	C7	C71	East of Tick I.	3.1	16,001.7 59,538.2	n.r.	224.0	18.0	100% P. crispus
June 26	D1	D11	N.E. of Rainy Pt.	1.5	15,977.5 59,596.5	n.r.	373.0	23.0	90% M. spicatum 10% Vallisneria
June 26	D1	D12	N.E. of Rainy Pt.	1.5	15,977.2 59,546.5	n.r.	1,267.0	175.0	70% M. spicatum 25% Chara, Elodea Vallisneria

n.a.* - Sample location not along transect
n.r.* - Data not recorded

Appendix E: Potamogeton crispus Loss on Ignition and Tissue Nutrient Data, 1987

Code	Date	Location	L.O.I. (%)	P (mg/g)	N (mg/g)	K (mg/g)
GL-1	June 3	Off Gores Landing Public Wharf	55.89	2.103	16.30	12.95
GL-2	"	"	54.10	1.548	16.70	16.6
GL-3	"	"	68.44	1.535	14.09	21.72
GL-4	"	"	59.23	1.222	12.08	18.56
SI-1	June 5	Adjacent limnocorral NE Sheep Island	55.58	0.891	14.09	20.14
SI-2	"	NE Sheep Island	59.34	1.065	14.98	24.86
SS-1	"	S Sheep Island	60.32	1.022	11.83	19.15
SS-2	"	"	58.72	1.244	11.59	21.97
J-11-1a	June 11	S of Harmony Island	65.69	1.110	14.62	23.46
J-11-1b	"	"	76.63	1.465	15.47	14.72
J-11-1c	"	"	59.23	1.147	9.74	12.96
J-11-2a	"	NE of Ley Pt.	68.69	1.316	13.60	26.63
J-11-2b	"	"	69.51	1.207	12.81	27.2
J-11-3a	"	W of Wallace Pt. toward Pine Tree Pt.	79.73	1.807	16.68	21.55
J-11-3b	"	"	63.47	1.232	16.00	17.86
J-14-1a	June 14	W of Tick Island	40.74	0.587	8.24	9.09
J-14-1b	"	"	51.13	0.798	10.73	13.01
J14-1c	"	"	76.46	1.671	14.61	18.14
J-14-2a	"	300 m E of Spook Island	56.84	1.369	15.90	17.64
J-14-2b	"	1 km E of Spook Island	44.42	0.881	12.29	11.35
Limnocorral	"	E Side Sheep Island	67.80	1.701	10.98	17.5
		Avg.	61.52	1.28	13.49	18.43

Appendix F: Potamogeton crispus Loss on Ignition and Tissue Nutrient Data, 1986

Code	Date	Location	Treatment	W. Vol. (ml)	W. Mass (g)	D. Mass (g)	L.O.I. (%)	A.F.D.M (g)	P (mg/g)	N (%)	K (mg/g)
C1	12/08/86	Goose Crk.	no acid	55	54	9.2	82.77	7.61			
C2	"	"	"	65	58.8	9.6	83.84	8.05			
C3	"	"	"	45	40.8	6.25	79.43	4.96			
C10	"	"	acid	120	113.7	18.3	82	15.01	19.6	2.7	10
C20	"	"	"	60	44.7	7.6	83.17	6.32	28.1	2.97	11.1
C30	25/06/86	Lim. Cor.	"		1490	132	79.66	105.15	10	1.771	11.9
C40	"	"	"		619.6	57	81.99	46.73	10.2	1.862	11.7
C50	"	"	"		1178	106	83.42	88.43	13.8	1.8	14
C60	28/06/86	E. Spook I	"		207	17.8	85.34	15.19	12	2.54	3.3
C70	18/07/86	Oton. R.	"		94	7.8	78.83	6.15	22.4	3.017	11.2
CF1	12/08/86	Goose Crk.	frozen						13.8	2.412	7.62
CF2	"	"	"			Avg. L.O.I.	82.045		26.4	3.385	8.5
CF3	"	"	"						22.6	2.16	8.75
CF4	"	"	"						19.6	3.175	8.8
CF5	"	"	"						10	2.28	5.55
							Avg. Nutrient Content		17.375	2.506	9.368333
							Limnocorrals Only		11.33	1.811	12.53333
							Limnos' + main lk.		13.68	2.198	10.42
							(of AFDM)				

Appendix G: Comparative Tissue Nutrient Analysis Results, 1987

	BARR				TRENT			
Code	LOI (%)	N (mg/g)	P (mg/g	K (mg/g)	LOI (%)	N (mg/g)	P (mg/g)	K (mg/g)
RL-1	62.95	19.8	2.50	16.1	55.89	16.3	2.10	12.95
RL-2	70.89	13.7	1.40	15.2	68.44	14.09	1.53	21.72
RL-3	75.80	10.9	1.24	16.2	55.58	12.99	0.89	20.14
RL-4	74.24	11.4	1.23	16.0	59.34	14.98	1.06	24.86
RL-5	64.58	11.4	1.14	14.4	60.32	11.83	1.02	19.15
RL-6	81.01	15.1	1.26	13.1	65.69	14.62	1.11	23.46
RL-7	76.67	14.3	1.33	18.8	69.51	12.81	1.21	27.20
RL-8	78.95	16.9	1.68	22.3	79.73	16.68	1.87	21.55
RL-9	79.47	18.0	2.25	16.1	76.46	14.61	1.67	18.14
RL-10	64.39	14.0	1.35	10.9	56.84	15.90	1.37	17.64
	-----	-----	-----	-----	-----	-----	-----	-----
Avg.	72.89	14.50	1.53	15.91	64.78	14.48	1.37	20.68

* BARR - Barringer Magenta laboratories
TRENT - Trent University, Ontario

Appendix H: Fathometer Transects, September, 1986

Date	Transect	General Location	Depths Covered(m)	Macrophyte Status
Sept. 3	A1	West of Ley Pt., to 30D W of N	.5 to 2.5 (2.5)	Slight milfoil growth initially
Sept. 3	A2	West of Ley Pt., 30D W of N	.5 to 2.5 (2.5)	Mixed community growth to 1m
Sept. 3	A3	E of Bewdley to W of Bewdley	.5 to .5 (3)	Milfoil growth to 2m, some thin milfoil growth to 3m
Sept. 3	A4	Creek east of Bewdley to 20D E of N	.5 to .5 (3.3)	Thin and discontinuous growth to 3m
Sept. 3	A5	Mid Harmony Isl. toward Ley Pt.	.5 to 4 (4)	Mixed community nearshore, milfoil growth to 2m
Sept. 3	A6	N of Harmony Isl. toward Halstead Beach	.5 to 5 (5)	Very thin milfoil growth in waters 2.5 to 3m
Sept. 3	B1	Bay near Wallace Pt. toward Ley Pt.	.5 to 2.5 (2.5)	Thin band of mixed community growth nearshore
Sept. 4	B2	Gores Landing	.5 to .5 (2.2)	Mixed growth nearshore at starting point
Sept. 4	B3	Causeway at Close Pt. toward Black Isl.	.5 to 3 (3)	Mixed community nearshore, predominately Elodea
Sept. 4	B4	Middle of Black Isl. to Sheep Isl.	.5 to .5 (2.5)	Barren of macrophytes
Sept. 4	B5	Sheep Isl. toward Jubilee Pt.	.5 to 3 (3)	Barren of macrophytes
Sept. 4	B6	Bay east of Close Pt. toward Spook Isl.	.5 to 3 (3)	Mixed community nearshore to 1.5m
Sept. 4	B7	Close Pt. S to mainland	.5 to .5 (2.5)	Mixed community nearshore, predominantly Vallisneria
Sept. 4	C1	Bay west of Harwood toward Tick Isl.	.5 to .5 (4)	Mixed community nearshore, some milfoil on 2m ridges
Sept. 4	C2	Bay E of Harwood toward Herkimer Pt.	.5 to 3.3 (3.3)	Thin milfoil to 2m, some mixed community to 1.5m
Sept. 5	B8	Long Isl. to marina north of Cow Isl.	.5 to .5 (2.5)	Mixed community near Long Island
Sept. 5	B9/1	Bay near Woodduck Creek	.5 to .5 (1.8)	Continuous but thin milfoil growth
Sept. 5	B9/2	Bay near Woodduck Creek	.5 to .5 (1)	Continuous but thin milfoil growth
Sept. 5	B10	Bay NW of Cow Isl. toward Long Isl.	.5 to .5 (2.5)	Mixed community to 1.5m, thin milfoil growth to 2m
Sept. 5	B11	Otonabee R. toward Sheep Isl.	.5 to 2.5 (2.5)	Heavy growth of mixed community to 2m
Sept. 5	B12	Ontonabee R. toward Tick Island	.5 to 2.2 (2.2)	Mixed community growth to 1.2m, Vallisneria to 2m
Sept. 5	B13	Otonabee R. toward Spook Isl.	.5 to 2.4 (2.4)	Heavy mixed growth, Vallisneria to 2m
Sept. 8	C3	Curtis Pt. N toward Sugar Isl.	.5 to 2.6 (2.6)	Milfoil nearshore to 2m

* Initial and final depths of fathometer transect. Bracketed figure is maximum depth recorded.

Appendix H: Fathometer Transects, September, 1986 (cont'd)

Date	Transect	General Location	Depths Covered(m)	Macrophyte Status
Sept. 8	C4	East of Curtis Pt. toward Serpent Mounds	.5 to 3.6 (3.6)*	Mixed community to 1m, continuous milfoil to 2.25m
Sept. 8	C5	Near Shearer Pt. N toward Foley Pt.	.5 to 4.3 (4.3)	Continuous but thin milfoil growth to 2.25m
Sept. 8	C6	Rack Isl. toward Roach Pt.	.5 to 4.4 (4.4)	Milfoil growth to 1.75m
Sept. 8	C7	Shore west of White Isl. to White Isl.	.5 to .5 (1.8)	Continuous milfoil growth
Sept. 8	C8	White Isl. south to mainland	.5 to .5 (2.5)	Heavy and continuous milfoil growth
Sept. 8	C9	South end of White Isl. NE to mainland	.5 to .5 (2.5)	Continuous milfoil growth
Sept. 8	C10	Shore east of White Isl. to Hickory Isl.	.5 to .5 (3.5)	Discontinuous milfoil growth to 3m
Sept. 8	C11	East Grape Isl. SW to Rack Island	.5 to .5 (3)	Continuous milfoil between Rack and White Isl.
Sept. 8	D1	McKracken Landing to Margaret Isl.	.5 to .5 (3.5)	Thin growth of milfoil to 2.5m
Sept. 8	D2	North end of Margaret Isl. E to mainland	.5 to .5 (3)	Thick but discontinuous milfoil growth to 2.8m
Sept. 9	D3	Eastern portion of lake	.5 to 4 (4)	Thin milfoil in 2.5m
Sept. 9	D4	Eastern portion of lake	.5 to 4.5 (4.5)	Mixed community growth initially, milfoil to 2.5m
Sept. 9	D5	Mainland to Lower Foley Isl.	.5 to .5 (3)	Mixed community growth initially, milfoil to 2.5m
Sept. 9	D6	Mainland toward Grasshopper Isl.	.5 to 5 (5)	Mixed community growth initially, milfoil to 2.5m
Sept. 9	E1	Foley Pt. SE toward East Grape Isl.	.5 to 5 (5)	Continuous, thin milfoil growth to 2.5m
Sept. 10	E2	Sugar Isl. NE to Foley Pt.	.5 to .5 (1)	Continuous and heavy growth of mixed community
Sept. 10	E3	Sugar Isl. west to marsh near Indian R.	.5 to .5 (1)	Continuous growth of mixed community
Sept. 10	E4	Shearer Pt. N to Sugar Isl.	.5 to .5 (4)	Discontinuous mifoil growth from 1.75 to 2.0m
Sept. 10	E5	Sugar Isl. W to marina at Serpent Mnds.	.5 to .5 (1.8)	Continuous, heavy milfoil
Sept. 10	E6	Marina at Serpent Mnds. to Rainy Pt.	.5 to .5 (2.5)	Continuous milfoil, mixed community, P. crispus
Sept. 10	E7	Rainy Pt. to Prison Isl.	.5 to .5 (3)	Discontinuous growth of milfoil, heavy at points
Sept. 10	E8	Harris Isl. N to McGregor Bay	.5 to .5 (1.8)	Mainly barren, turbid water conditions
Sept. 12	F1	Plum Pt. SW to marsh perimeter	.5 to .5 (1.8)	Mainly barren, turbid water conditions
Sept. 12	F2	Harris Isl. S toward Paudaush Isl.	.5 to .5 (1.8)	Continuous growth of milfoil and mixed community
Sept. 12	F3	Harris Isl. SE toward Curtis Pt.	.5 to 3.5 (3.5)	Mixed community growth initially, milfoil to 2m

* Initial and final depths of fathometer transect. Bracketed figure is maximum depth recorded

Appendix I: Biomass Sampling Results, September, 1986

Date	Transect	Sample Code	General Location	Depth (m)	Loran C Coordinates	Wet Volume (ml/m^2)	Wet Mass (g/m^2)	Dry Mass (g/m^2)	Species Composition
Sept. 3	A3	A3/1	Bewdley	1.85	16,039.3 59,493.1	847.0	690.0	88.0	100% M. spicatum
Sept. 3	A3	A3/2	Bewdley	1.4	16,039.6 54,492.5	153.0	140.7	21.9	100% M. spicatum
Sept. 5	B8	B8/1	N.E. Long I.	0.75	16,014.4 59,510.3	813.0	706.0	47.0	60% Vallisneria 38% P. crispus 2% Elodea
Sept. 9	E1	E1/1	Foley Pt.	0.8	15,963.6 59,544.1	527.0	418.0	76.5	100% M. spicatum
Sept. 9	E2	E2/1	N. Sugar I.	0.9	15,964.1 59,549.2	4,957.3	3,712.0	n.r.*	85% Elodea 10% M. spicatum 5% H. dubia
Sept. 9	C4	C4/1	East of Curtis Pt.	1.2	15,981.5 59,533.1	1,520.0	1,279.2	161.6	100% M. spicatum
Sept. 11	n.a.*	D1	South of White I.	1.0	15,979.6 59,576.8	3,113.0	3,024.5	484.6	80% Chara 10% H. dubia 10% Vallisneria
Sept. 11	n.a.	D2	South of White I.	1.5	15,979.0 59,561.9	307.0	296.0	28.8	Mixed Community Species breakdown not recorded
Sept. 11	n.a.	W1	West of White I.	1.5	15,976.9 59,560.0	873.0	782.0	72.7	100% M. spicatum
Sept. 11	n.a.	W2	East of White I.	1.8	15,971.1 59,562.2	293.0	275.0	24.7	100% M. spicatum

n.a.* - Sample location not along transect
n.r.* - Data not recorded

Appendix J: Summary of Loss on Ignition and Tissue Nutrient Data, MOE, 1984

Species or Community	LOI (%)	P (mg/g)	N (mg/g)	N:P
Curly-leaf Pondweed	-	2.33	20.01	8.6
Milfoil	74.75	3.25	21.9	6.7
Mixed Community	70.13	3.78	24.84	6.5

Appendix K: Myriophyllum spicatum Loss on Ignition and Tissue Nutrient Data, 1986

Code	Date	Location	Treatment	W. Vol. (ml)	W. Mass (g)	D. Mass (g)	L.O.I. (%)	A.F.D.M. (g)	P (mg/g)	N (%)	K (mg/g)
MA1	30/07/86	Rack I.	acid	360	289	41.5	80.85	33.55275			
MA2	"	"	"	70	71	8.1	74.75	6.05475			
MA3	"	"	"	60	58	9	67.24	6.0516			
MA4	"	"	no acid	50	51.2	8.8	50.89	4.47832			
MA5	"	"	"	100	93.6	14.4	47.94	6.90336			
MA6	"	White I.	acid	270	229	26.9	69.89	18.80041			
MA7	"	"	"	260	216.5	23.7	77.23	18.30351			
MA8	"	"	"	55	45	4.3	77.48	3.33164			
MA9	"	"	no acid	360	285	35	73.37	25.6795			
MA10	"	Curtis Pt.	acid	360	289	41.5	77.66	32.2289			
MA11	"	"	"	70	71	8.1	67.93	5.50233			
MA12	"	"	"	60	58	9	49.65	4.4685			
MA13	"	"	no acid	50	51.2	8.8	49	4.312			
MA14	"	"	"	100	93.6	14.4	53.11	7.64784			
MA15	"	"	acid	30	26.5	3.1	86.48	2.68088			
MA16	"	"	"	25	26.1	2.6	85.74	2.22924			
MA17	"	"	"	130	112.7	16.5	86.83	14.32695			
MA18	"	"	no acid	55	44.1	4.2	84.17	3.53514			
MA19	"	"	"	20	30.2	5.9	80.92	4.77428			
M100	30/07/86	Rack I.	Frozen	130	115	19.8	47.98	9.50004	2.2	1.246	0.64
M200	"	White I.	"	235	194	28.5	63.52	18.1032	6	1.554	1.59
M300	"	Curtis Pt.	"	195	182.3	27.5	40.39	11.10725	3.8	1.512	0.34
M400	"	Curtis Pt.	"	140	109	13.1	89.01	11.66031	14.2	1.89	8.95
M500	"	Sugar I.	"				78.33		8	2.375	3.35
M600	"	Woodduck C.	"				73.74		12	2.233	2.11
M700	"	Rack I.	"				83.67		10.8	1.78	4.05
M800	"	Oton. R.	"				76.29		12.4	2.731	3.47
MF1	n.r.*	n.r.	"						4.2	1.768	2.7
MF2	n.r.	n.r.	"						3.8	1.971	2.82
MF3	n.r.	n.r.	"						5.6	1.985	2.85
MF4	n.r.	n.r.	"						6.6	1.572	2.77
MF5	n.r.	n.r.	"						7	1.761	3.18
					Average Nutrient Content (n=13) (of AFDM)				7.43 (mg/g)	1.86 (%)	3.00 (mg/g)

Average L.O.I. - 75.14% (acid bath, n=12)
- 66.15% (no acid bath, n=15)

n.r.* - Data not recorded

Appendix M: *Heteranthera dubia* Loss on Ignition and Tissue Nutrient Data, 1986

Code	Date	Location	Treatment	W. Vol. (ml)	W. Mass (g)	D. Mass (g)	L.O.I. (%)	A.F.D.M. (g)	P (mg/g)	N (%)	K (mg/g)
ZA1	30/07/86	Oton. R.	acid	70	53.5	3.7	77.81	2.87897			
ZA2	"	"	"	70	62	3.8	81.53	3.09814			
ZA3	"	I.P. Bay	"	85	67.5	6.4	78.9	5.0496			
ZA4	"	"	"	105	91	6.5	80.15	5.20975			
ZA5	"	"	"	95	85.6	6.6	79.62	5.25492			
ZA6	"	"	"	78	66.5	5.1	77.62	3.95862			
ZA7	"	"	"	120	101	7.7	82.52	6.35404			
ZA8	"	"	"	70	54.5	4.1	76.37	3.13117			
ZA9	"	"	"	80	68.8	7.3	78.77	5.75021			
Z10	"	"	no acid	65	59	5.1	71.93	3.66843			
Z11	"	"	"	60	46	4	67.43	2.6972			
Z12	"	"	"	80	81	6.4	63.79	4.08256			
Z13	"	"	"	65	61.5	4.9	70.63	3.46087			
Z14	"	"	"	95	84	7.1	70.36	4.99556			
Z15	"	"	"	60	57.3	5	65.26	3.263			
Z16	"	"	"	70	68	4	70.93	2.8372			
ZN10	"	Oton. R.	"	75	65.5	5	76.37	3.8185	20	2.56	13
ZN20	"	"	"	80	68	3.9	67.2	2.6208	20	2.935	8.3
ZN30	"	"	"	60	49	4.6	73.23	3.36858	11.8	1.988	6.48
ZN40	"	"	"	45	46	4.3	66.81	2.87283	7.8	2.009	7.58
					Average Nutrient Content (n=4) (of AFDM)				14.9 (mg/g)	2.375 (%)	8.84 (mg/g)

Average L.O.I. - 79.25% Acid Bath (n=9)
76.4% No Acid Bath (n=11)

Appendix N: Species List of Plants Collected from Rice Lake

Zonation	Scientific Name	Common Name	Habitat
Submerged	Bidens beckii	water marigold	L
	Ceratophyllum demersum	coontail	L
	Chara vulgaris	muskgrass	L,M
	Elodea canadensis	waterweed	L,(M)
	Heteranthera dubia	water stargrass	
	Myriophyllum spicatum	Eurasian watermilfoil	L
	Najas flexilis	bushy pondweed	M,(L)
	Potamogeton amplifolius	bigleaf pondweed	L
	Potamogeton crispus	curly-leaved pondweed	L
	Potamogeton natans	swimming pondweed	L
	Potamogeton pectinatus	sago pondweed	L
	Potamogeton richardsonii	redhead pondweed	L,(M)
	Utricularia vulgaris	common bladderwort	L,(M)
	Vallisneria americana	tape grass	L
Emergent	Pontederia cordata	pickerelweed	M
	Sagittaria latifolia	broad-leaved arrowhead	M
	Scirpus validus	bulrush	M
	Typha angustifolia	narrow-leaved cattail	M
Floating	Lemna minor	lesser duckweed	M
	Lemna trisulca	star duckweed	M
	Nuphar variegatum	spatterdock	M
	Nymphaea odorata	white waterlily	M
Terrestrial	Calamagrostis canadensis	blue-joint	M
	Carex pseudo-cyperus	cyperus-like sedge	M
	Chelone glabra	turtlehead	M
	Cicuta bulbifera	bulb-bearing water hemlock	M
	Cornus stolonifera	red-osier dogwood	M
	Decodon verticillatus	swamp loosestrife	M
	Dryopteris thelypteris	marsh fern	M
	Galium trifidum	bedstraw	M
	Lycopus americanus	cut-leaved water hoarhound	M
	Lythrum salicaria	purple loosestrife	M
	Myrica gale	sweet gale	M
	Salix candida	hoary willow	M
	Scutellaria lateriflora	blue skullcap	M

L - Lake
M - Marsh
( ) - indicates secondary habitat

Appendix O: Site Records for Plant Species from Rice Lake

Zonation	Scientific Name	Common Name	Habitat
Submerged	Ranunculus aquatilis	aquatic buttercup	L,M
Emergent	Sparganium sp.	bur reed	M
	Typha latifolia	broad-leaved cattail	M
Terrestrial	Alnus incana ssp. rugosa	speckled alder	M
	Impatiens biflora	jewelweed	M
	Iris pseudacorus	yellow flag	M
	Iris versicolor	blue flag	M
	Urtica dioica	stinging nettle	M

L - Lake
M - Marsh

Appendix P: Secchi Depth and Temperature Readings, Rice Lake, 1987

Date	Secchi Depth (m)	Temp. (O^C)
April 24	1.5	13
April 29	1.8	13
May 1	1.8	12
May 12	2.8	14.5
May 15	3.1	14.5
May 21	3.1	14
May 26	4.0	n.m.
May 28	4.8	18
June 1	4.5	22
June 4	4.3	n.m.

n.m. - not measured
- secchi depth and temperature readings taken in deep water portion of the lake between Sheep Island and Gores Landing
- temperature readings taken 15 cm below water surface